

Global HYCOM

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Naval Research Laboratory

8th Hybrid Coordinate Ocean Model Workshop

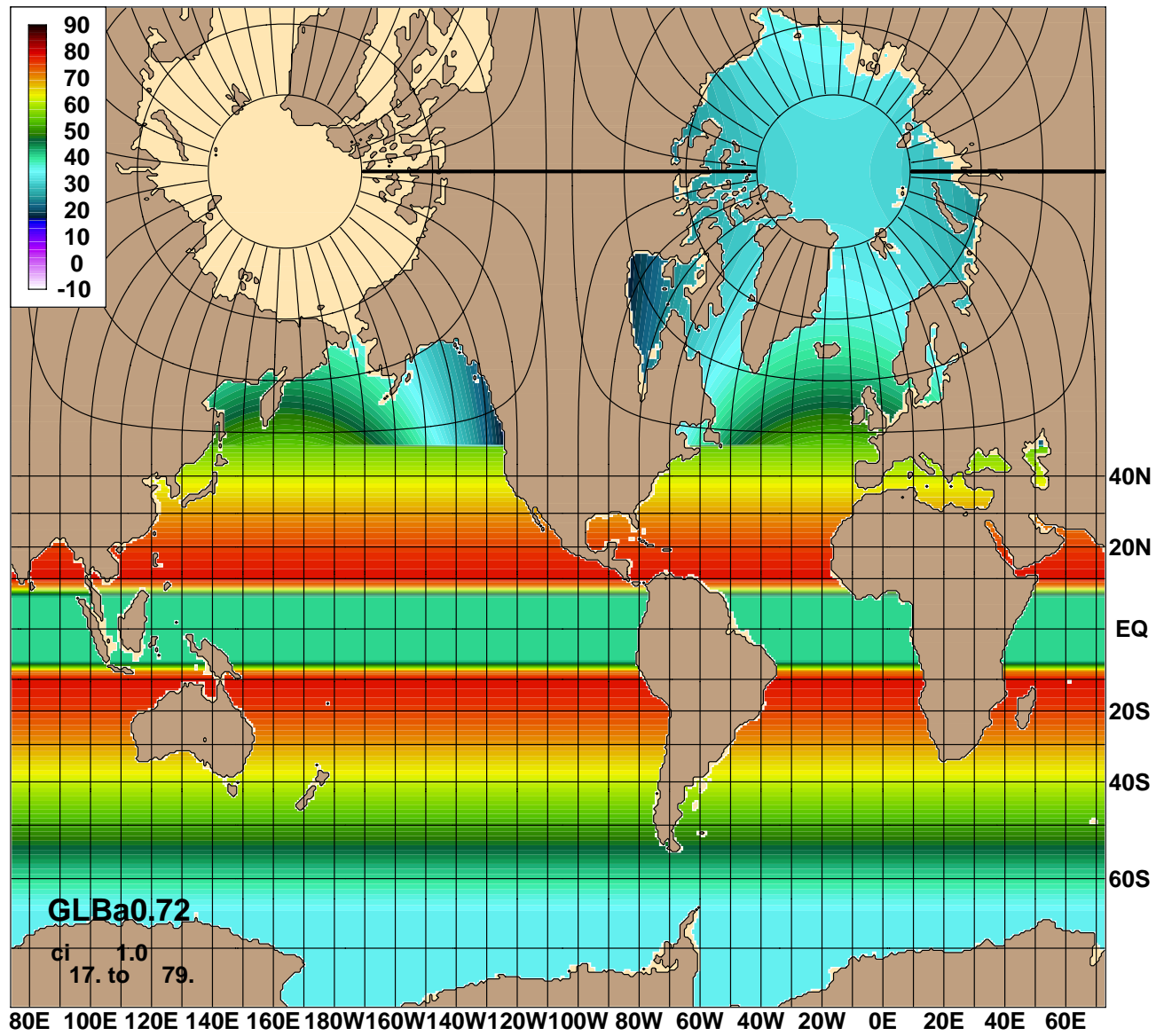
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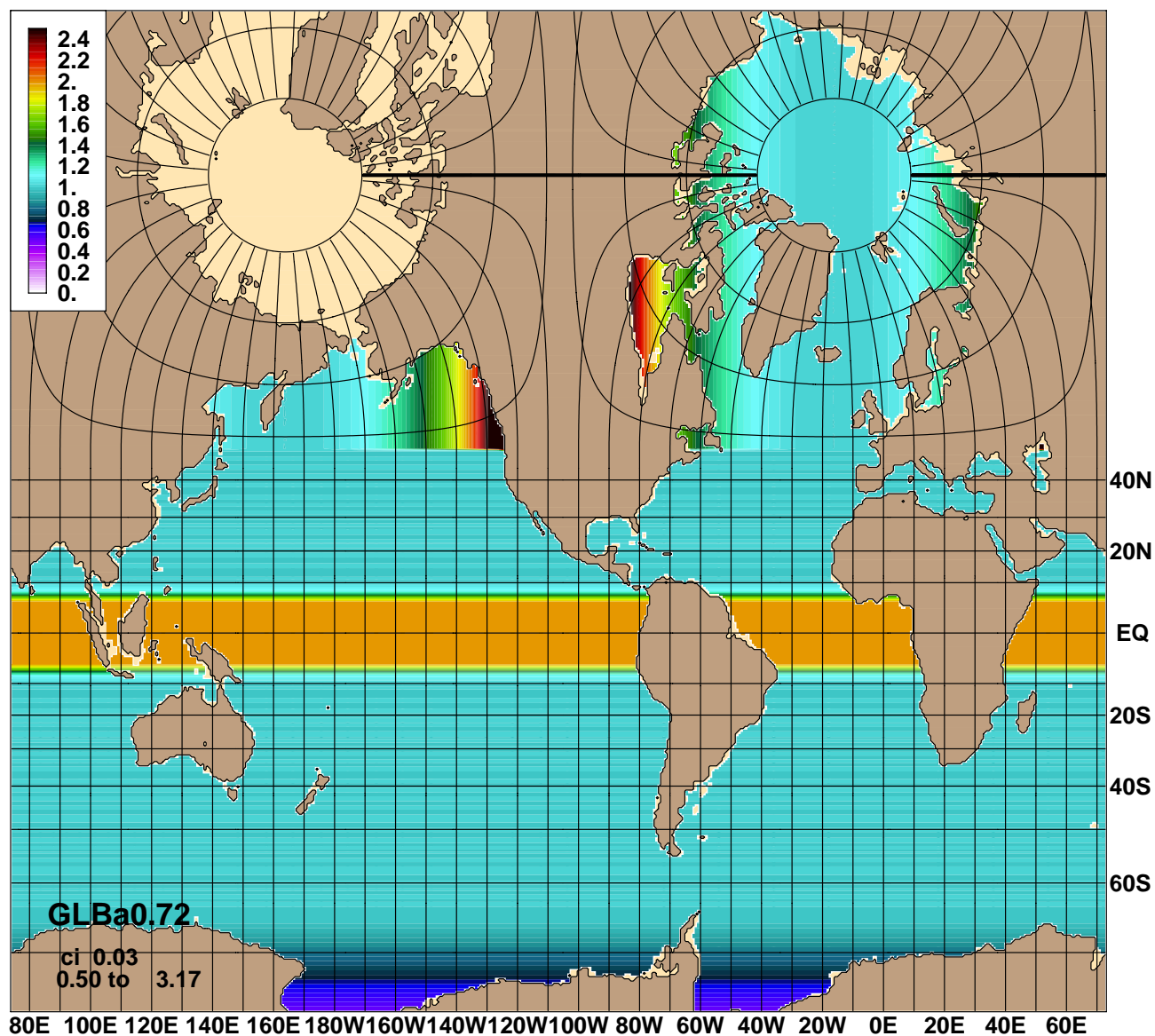
0.72 degree Global Domain

- Pan-Am Global Grid
 - 0.72 degree equatorial Mercator 78S-47N
 - Arctic bi-polar patch above 47N
 - * Low resolution global had patch at 59N
 - * Can't include Hudson Bay
 - Double latitudinal resolution near the equator
 - Halve latitudinal resolution in Antarctic
- Coastline at 50m isobath
 - Closed Bering Strait
 - No Sigma (terrain-following) vertical coordinate
- Same 26-layers as 0.08 degree Atlantic
- Two configurations for fixed coordinates:
 - First Z-level 3 m, increases 1.125x up to 12 m
 - First Z-level 3 m, increases 1.200x up to 60 m
- Also a 40-layer Z-coordinate case:
 - First Z-level 1 m, increases 1.190x up to 878 m

47N: SCPY (km)



47N: Grid Aspect Ratio (SCPX/SCPY)



Three global resolutions

- 0.72, 0.24 and 0.08 degrees
- 0.72 degrees is inexpensive and non-eddying
 - Only resolution run so far
- 0.08 degrees is expensive and eddy resolving
 - Target resolution for operational use at NAVO
 - Concentrate on Atlantic and Pacific at 0.08 in FY04
- 0.24 degrees is (marginally) eddy permitting
 - Primary resolution in FY04
- Starting point for 0.24 and 0.08 is a 0.04 coastline/bathymetry
 - Interpolated from NRL 2 minute bathymetry
 - Extensive quality control in straits and near coastlines
 - Still under preparation

0.72 degree Global Standard Configuration

- KPP mixed layer
- Energy-Loan ice model
- Sigma-theta (some sigma2 runs)
- Horizontal diffusion chosen to suppress eddies
- Initialize from GDEM3
- ECMWF Reanalysis monthly mean forcing
 - Plus 6-hrly wind anomalies from sep94-sep95
- Longwave correction w.r.t. ECMWF SST
- Inexpensive approximation to COARE 2.6 bulk heat flux parameterization
- Monthly means of 15 largest rivers via precip bogus
- Strong relaxation to monthly GDEM3 SSS
 - “30 days in 30 m” e-folding time
 - Necessary to prevent SSS drift
 - In addition to E-P forcing (monthly P)

Longwave Radiation and SST

- Longwave Radiation is sum of:
 - Upward blackbody longwave radiation
 - * $Q_{bb} = -0.98 (5.67 \times 10^{-8}) (T_s + 273.16)^4$
 - Downward atmospheric longwave flux
 - * Highly dependent on cloudiness
 - * Unknown dependence on SST (assume independent)
- If longwave was calculated using a SST of T_{so} :
 - $Q_{lw}(T_s) = Q_{lw}(T_{so}) + Q_{bb}(T_s) - Q_{bb}(T_{so})$
 - $Q_{lw}(T_s) = Q_{lw}(T_{so}) + Q'_{bb}(T_s - T_{so})$
 - $Q'_{bb} = -0.98 (5.67 \times 10^{-8}) 4 (T_s + 273.16)^3$
- Ocean Model Intercomparison Project includes $(Q_{bb}(T_s) - Q_{bb}(T_{so}))$ as a longwave correction
- HYCOM uses the approximation (in W/m^2):
 - $Q'_{bb} = -4.506 - 0.0554 T_s$
- This is similar to “30 days in 3.5 m” SST relaxation
 - 10x weaker than typically SSS relaxation

SST Metrics I

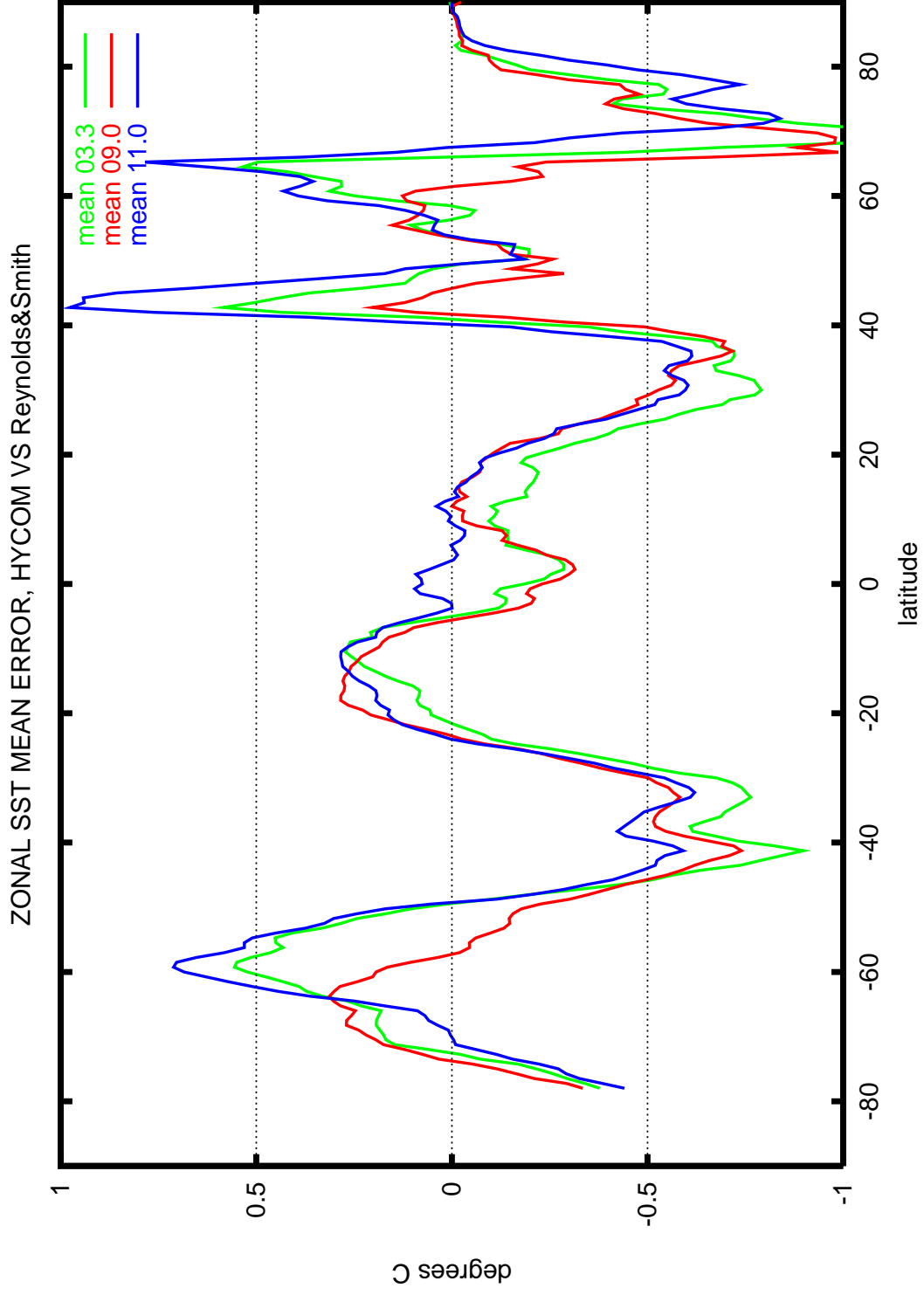
- Run for 5 years and form monthly means
 - Takes two days on 64 IBM POWER4 cpus
 - 25 year run gives “similar” SST
- Compare monthly SST to Reynolds and Smith climatology
 - Monthly anomalies
 - Annual mean difference
 - RMS difference
 - Correlation Coefficient
 - Skill Score
 - * Correlation squared - Unconditional Bias - Conditional Bias
 - * Maximum is 1, but minimum is -infinity
 - * Measure of error w.r.t. seasonal cycle (i.e. w.r.t. standard deviation)
 - * Use a minimum of 1 degC for standard deviation
 - Still get poor skill scores near equator

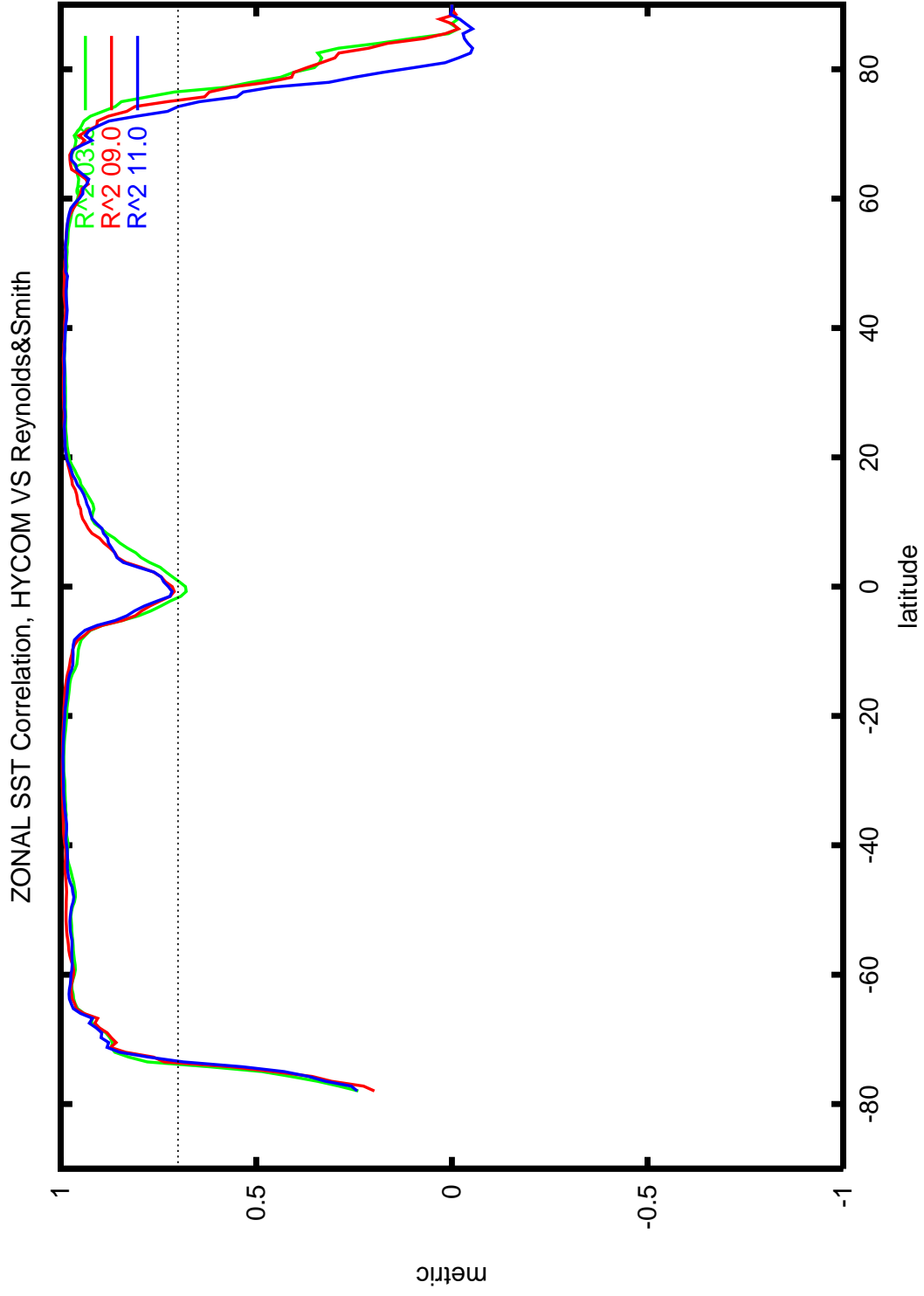
SST Metrics II

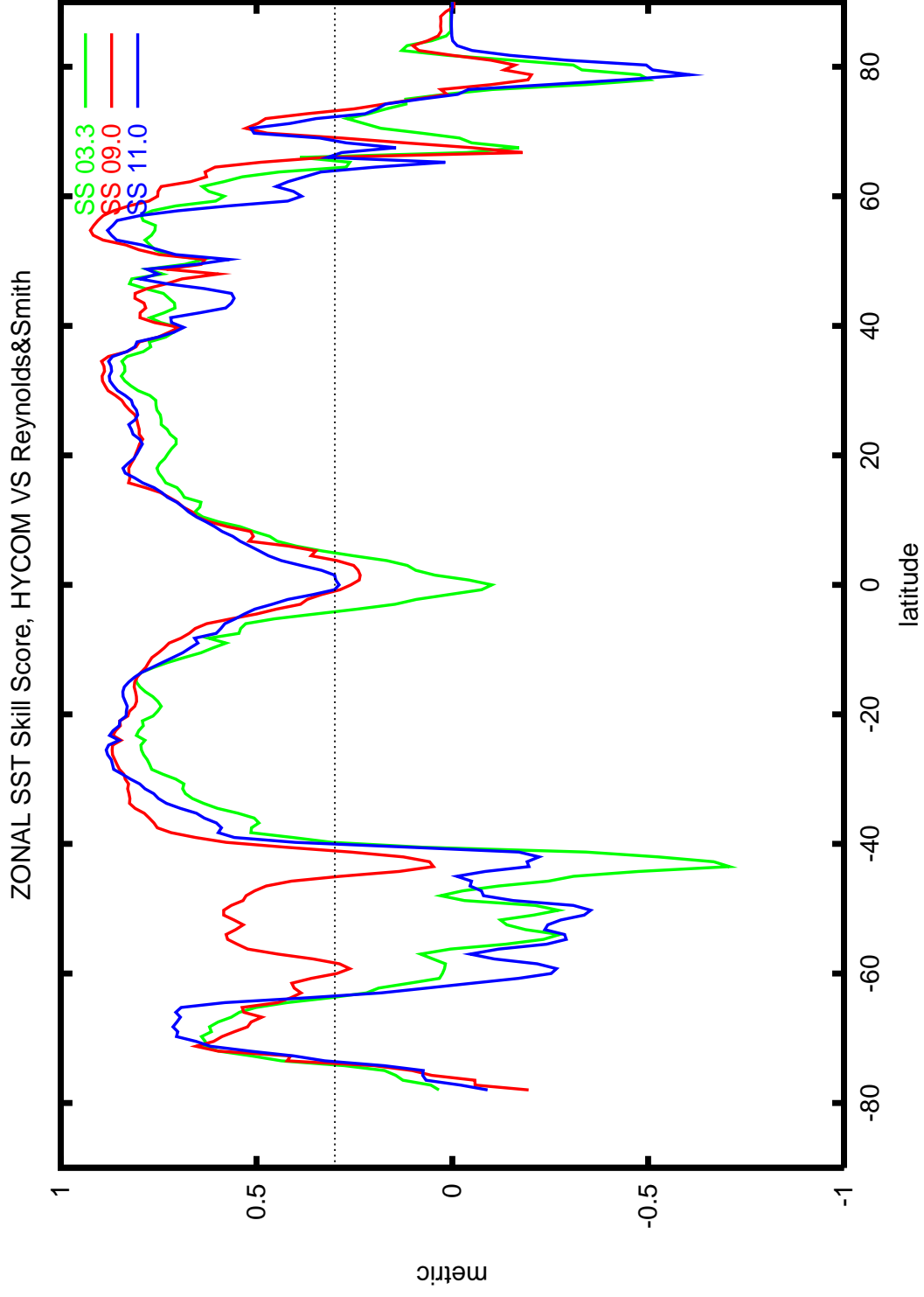
- Purpose of comparison is to find “good enough” configuration
 - Assume that “skill” on climatological forcing is maintained on interannual forcing
 - Is monthly thermal climatological forcing enough?
 - NLOM experience suggests that this is OK, but can’t be certain until we run more interannual cases with HYCOM
- Targets:
 - Annual mean error < 0.5 degC
 - Correlation Coefficient > 0.6
 - Skill Score > 0.3
- Use zonal averages to reduce amount of data
 - Average not necessarily best statistic
 - * A few large negative skill scores can dominate the average
 - Same targets as for full field

Simulation History

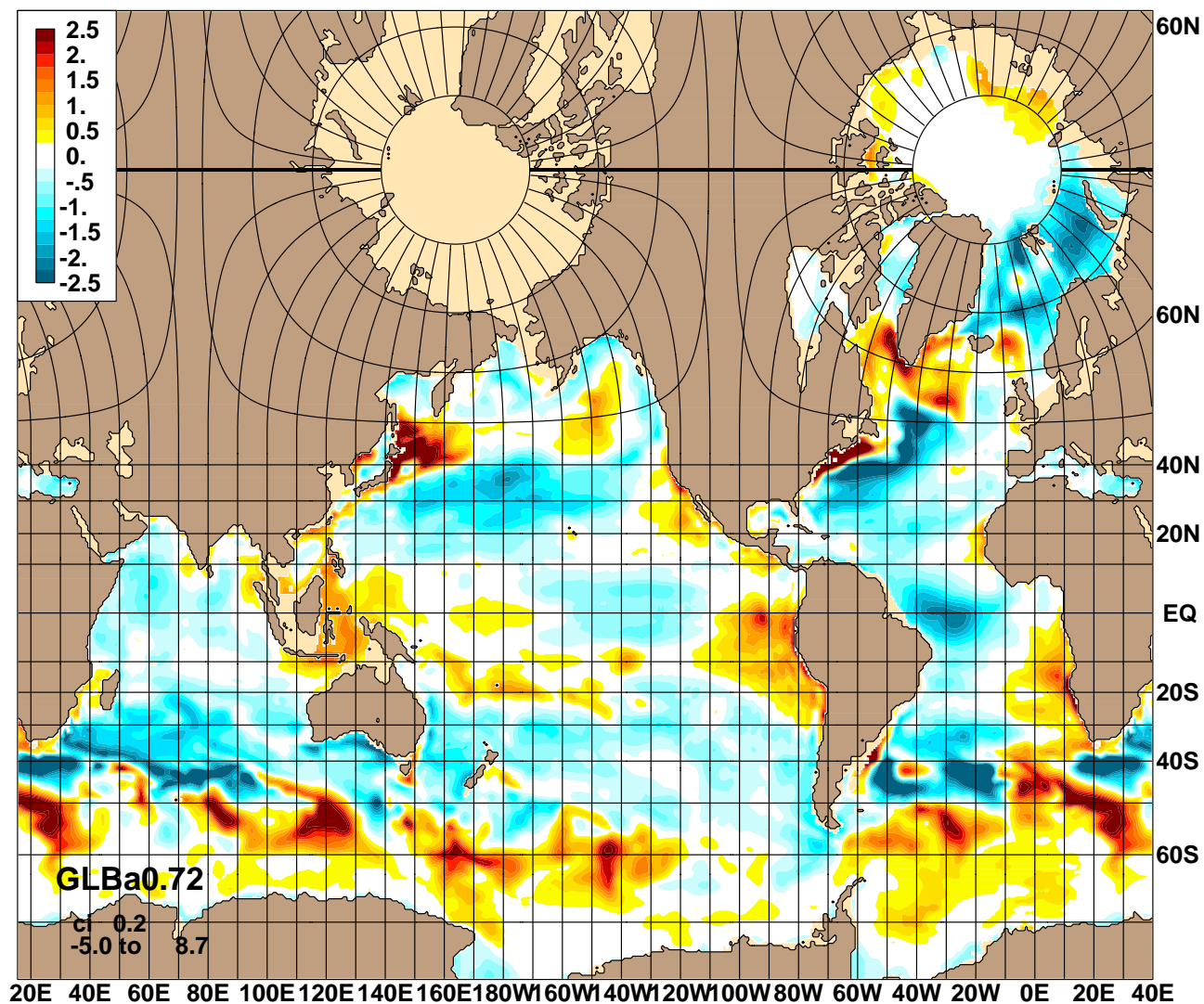
- Expt 3.3:
 - Best as of February 2003
 - Levitus climatology
 - Annual rivers
 - “Longwave” via SST relaxation
- Expt 9.0:
 - 40 Z-level case
 - PLM vertical remapping
- Expt 11.0:
 - Standard sigma-theta case
 - 3m-12m Z levels
 - Thin deep isopycnal layers



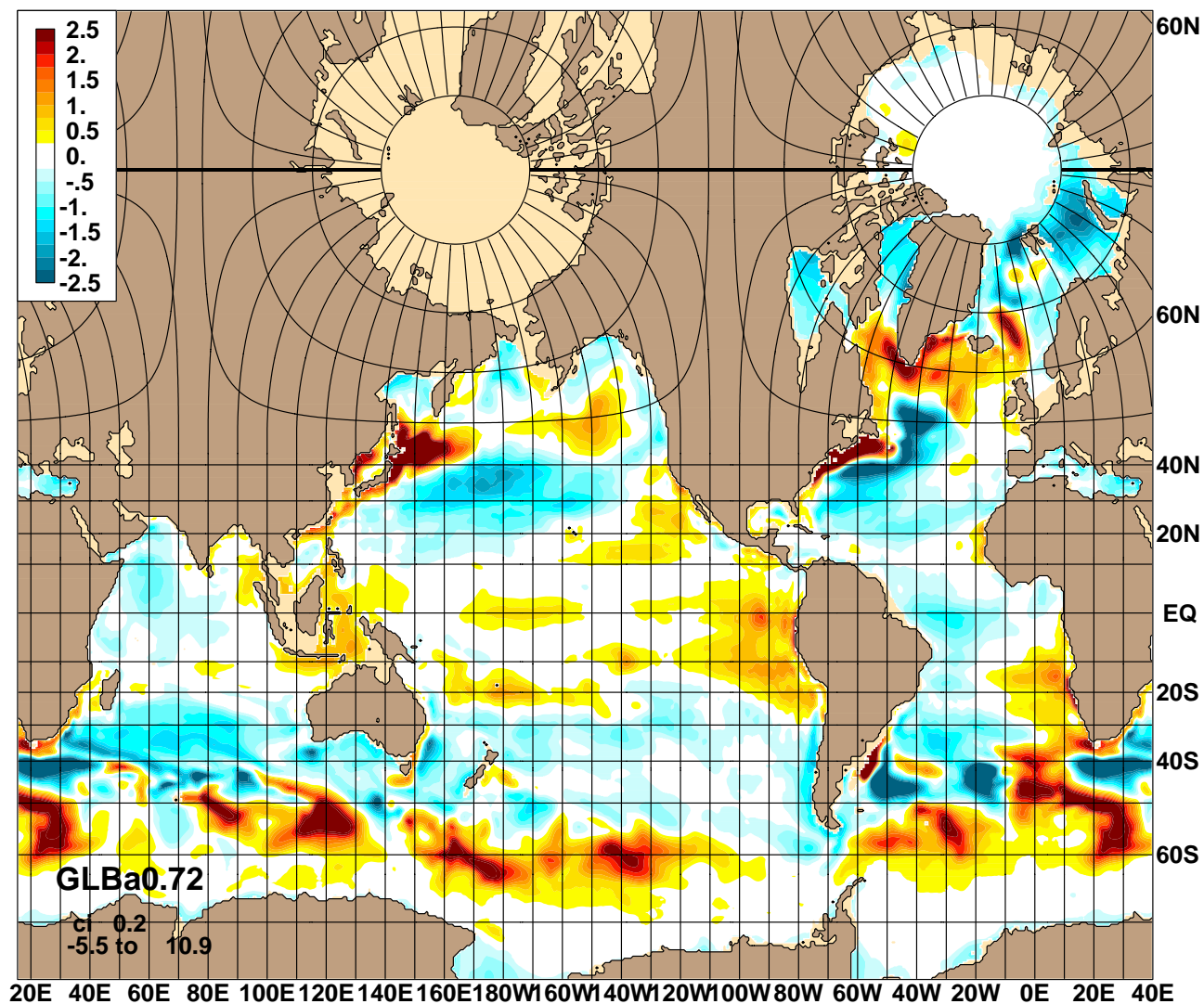




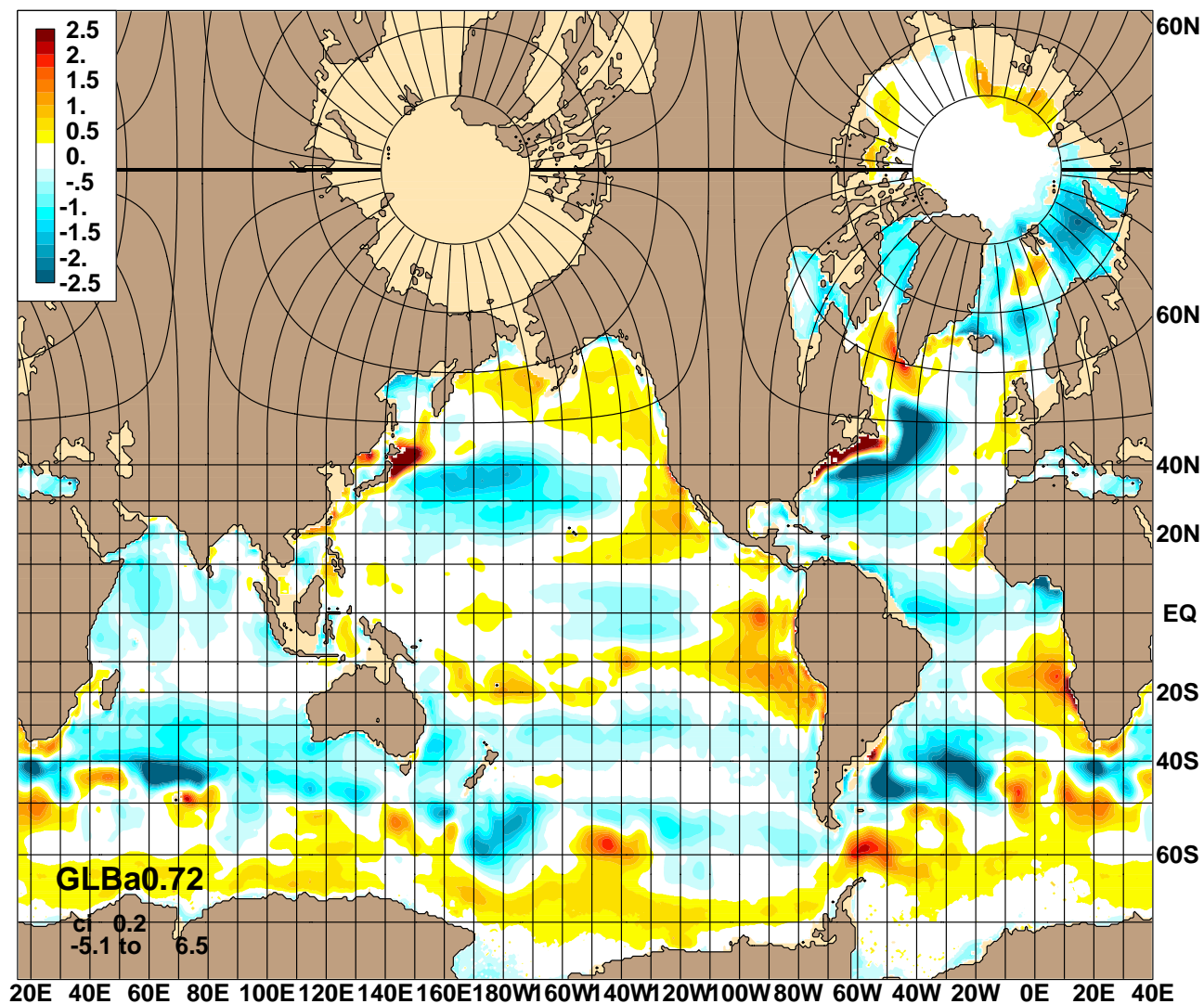
03.3 vs R&S SST: Mean Error



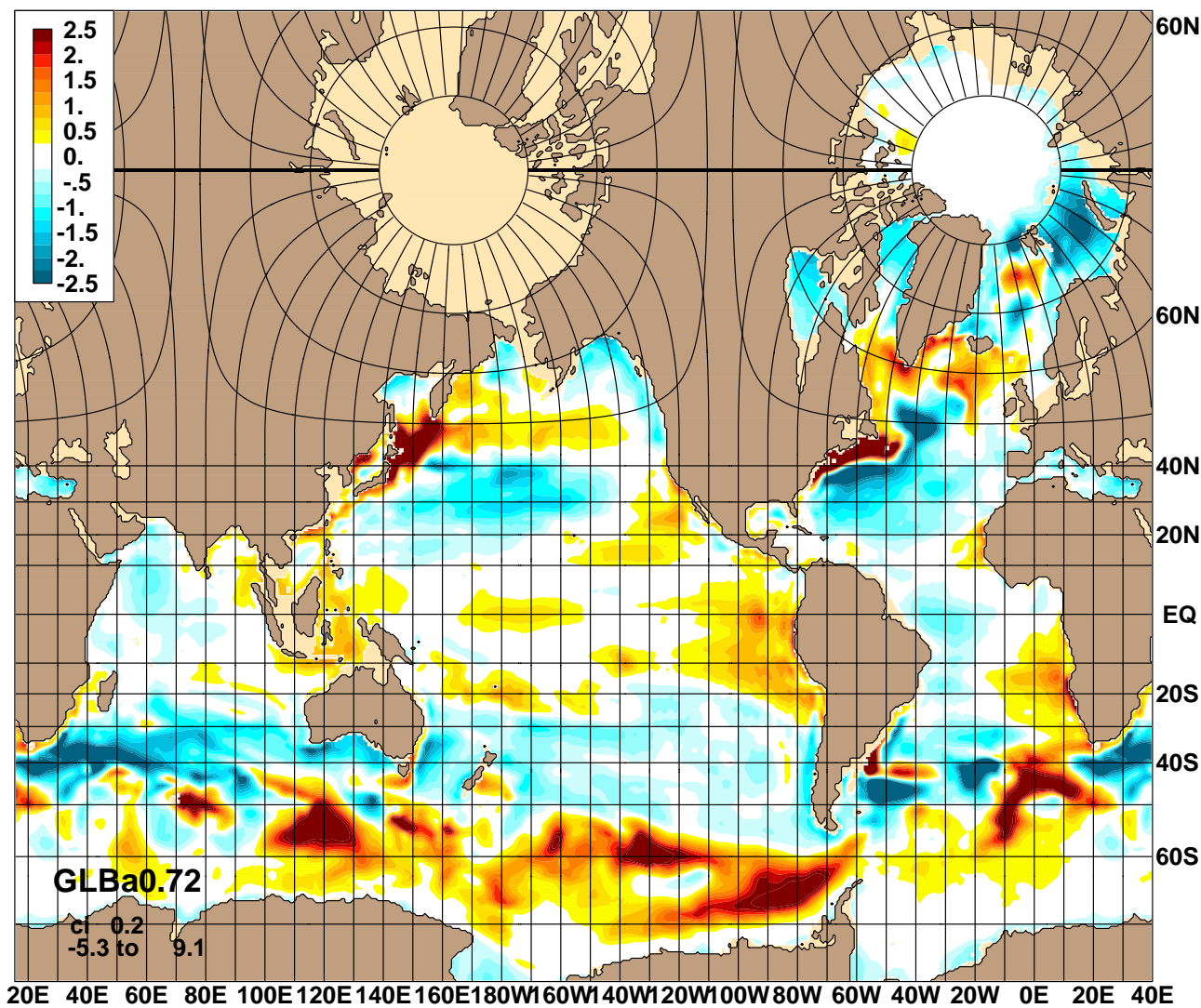
11.0 vs R&S SST: Mean Error



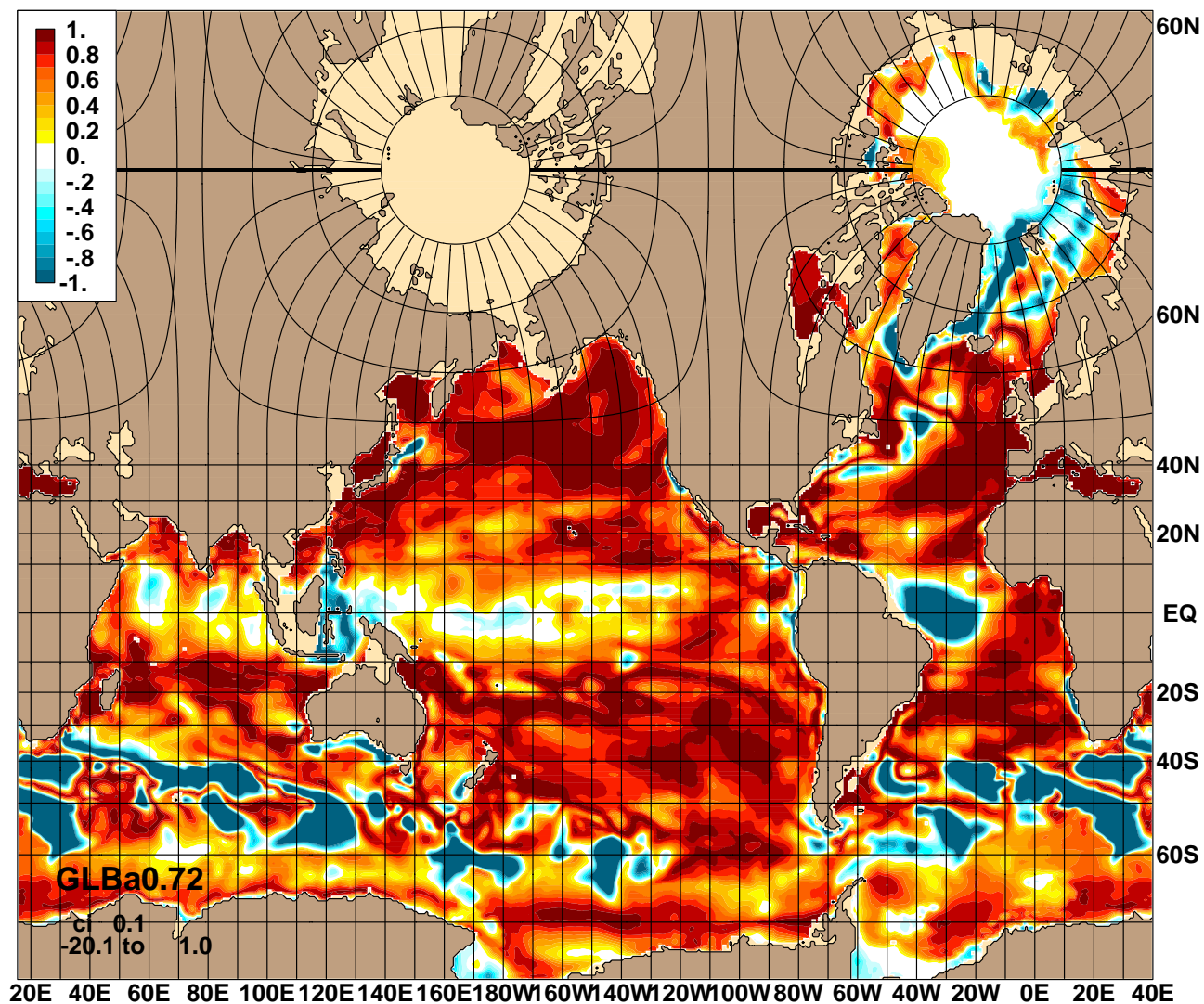
09.0 vs R&S SST: Mean Error



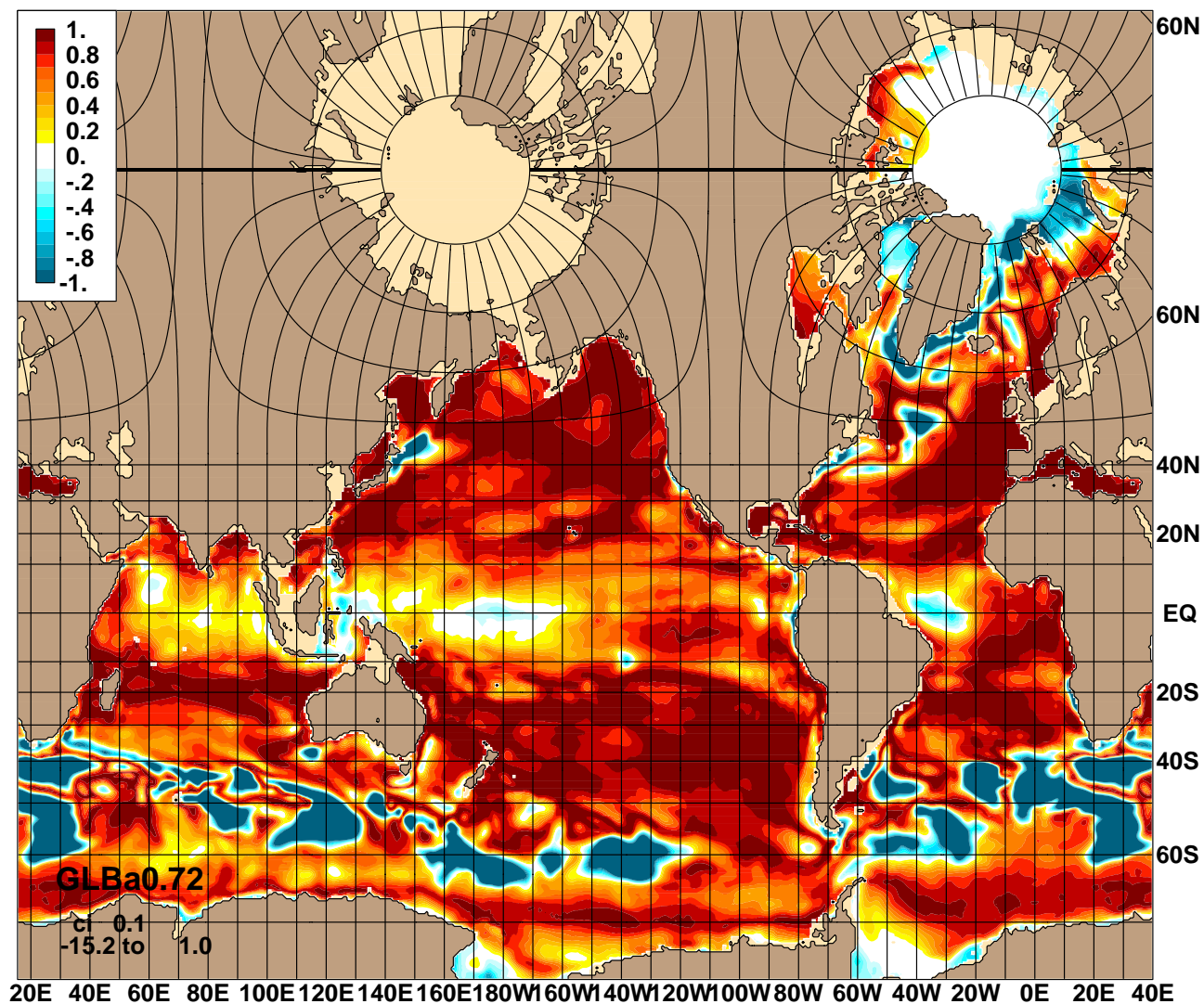
11.0 vs R&S SST: Mean Error yr 25



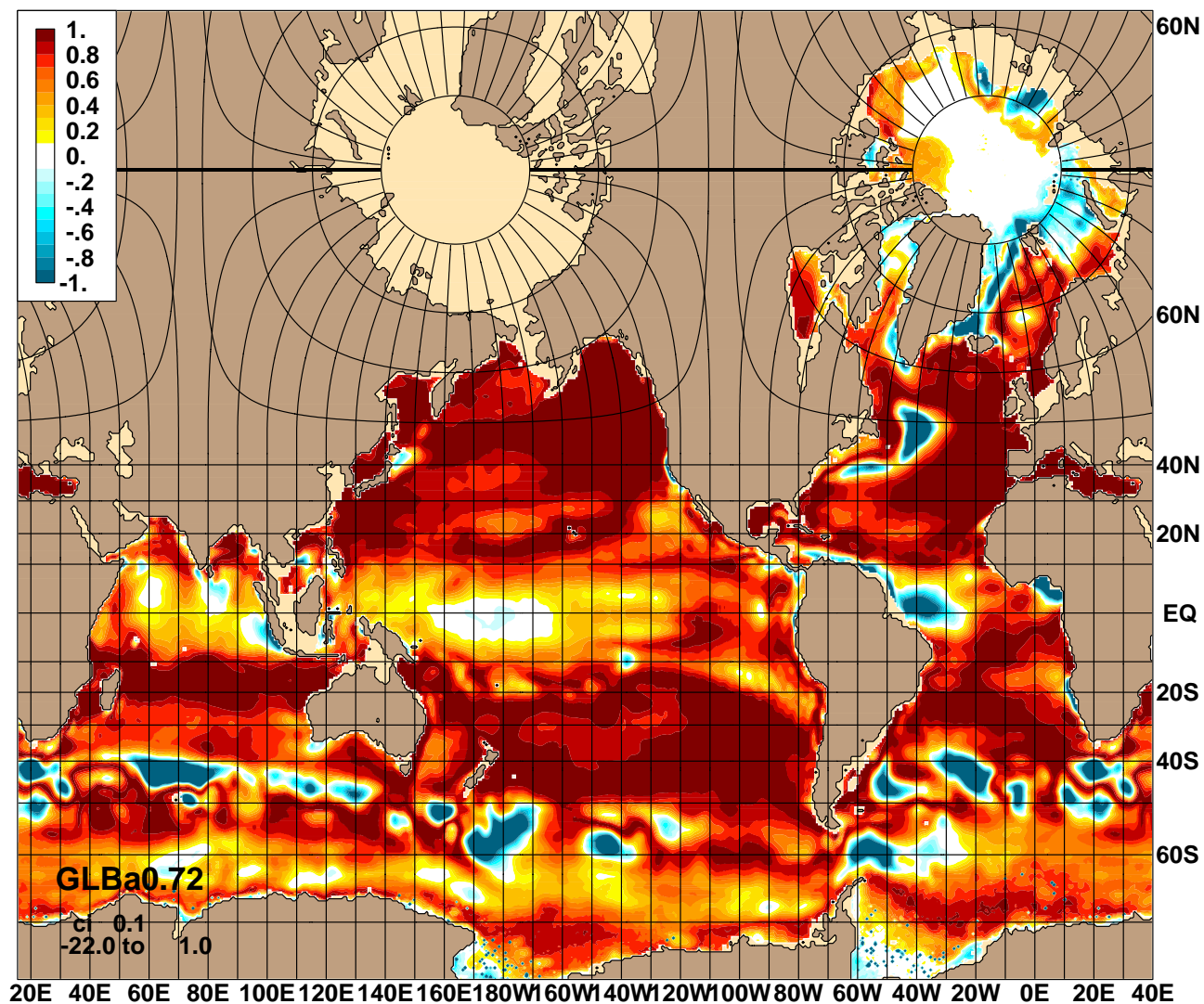
03.3 vs R&S SST: Skill Score



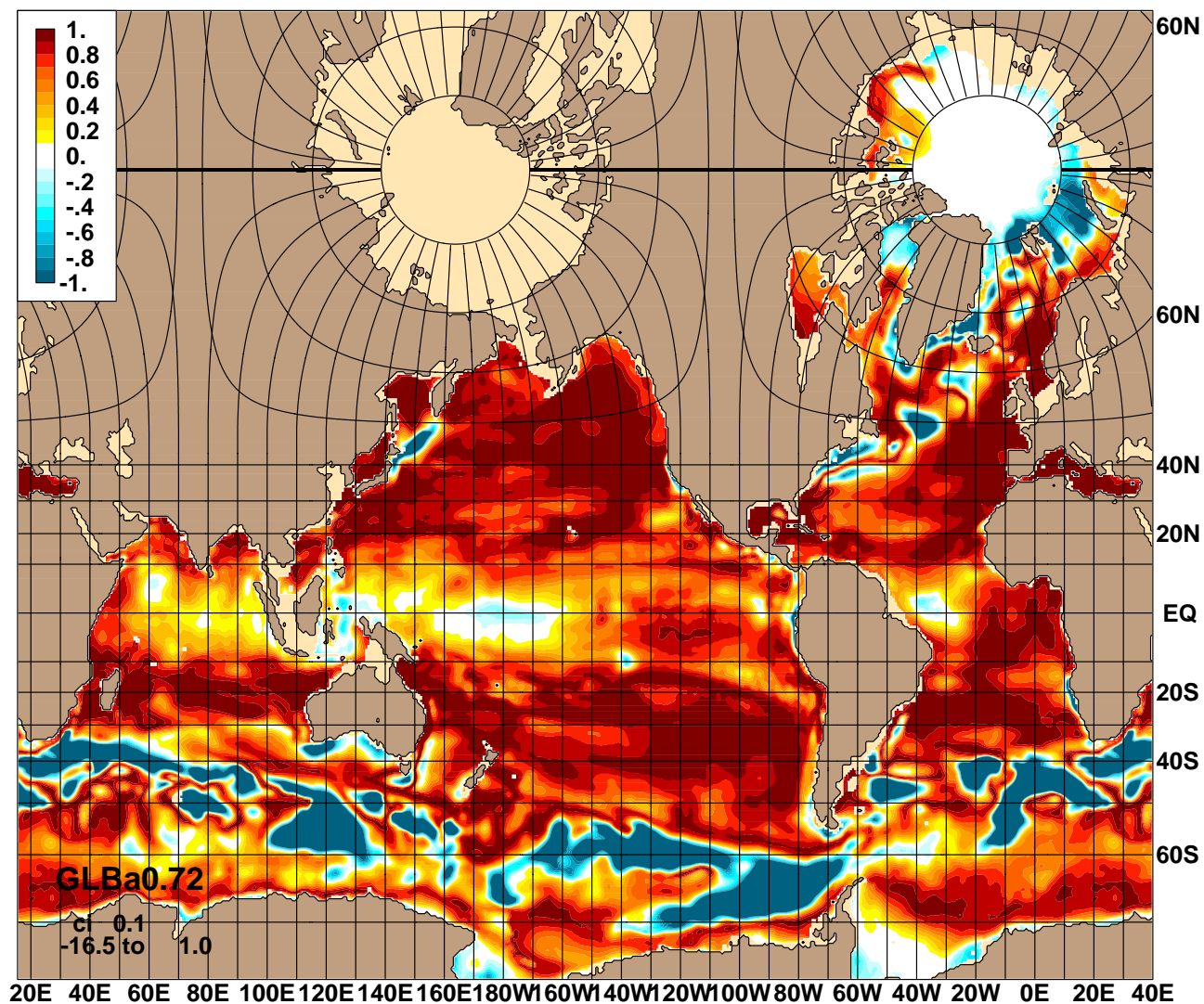
11.0 vs R&S SST: Skill Score



09.0 vs R&S SST: Skill Score



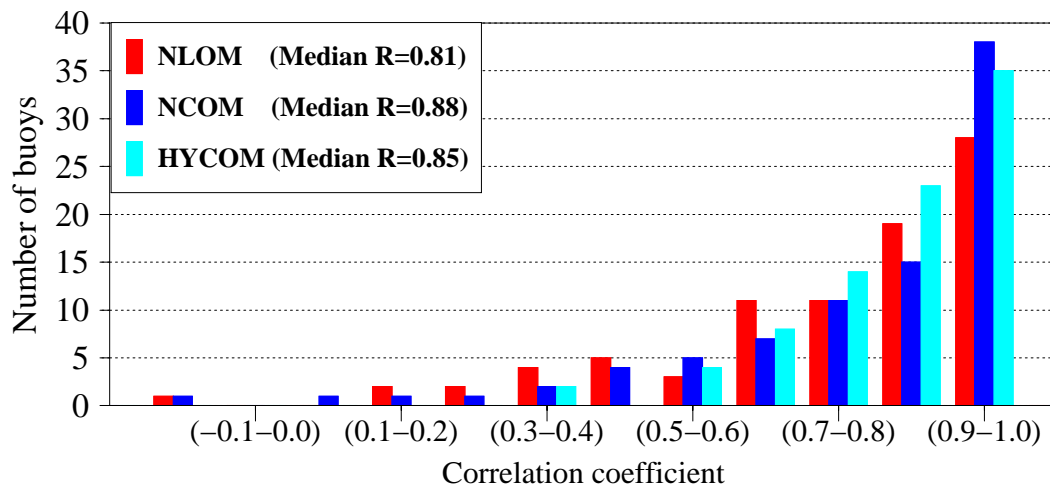
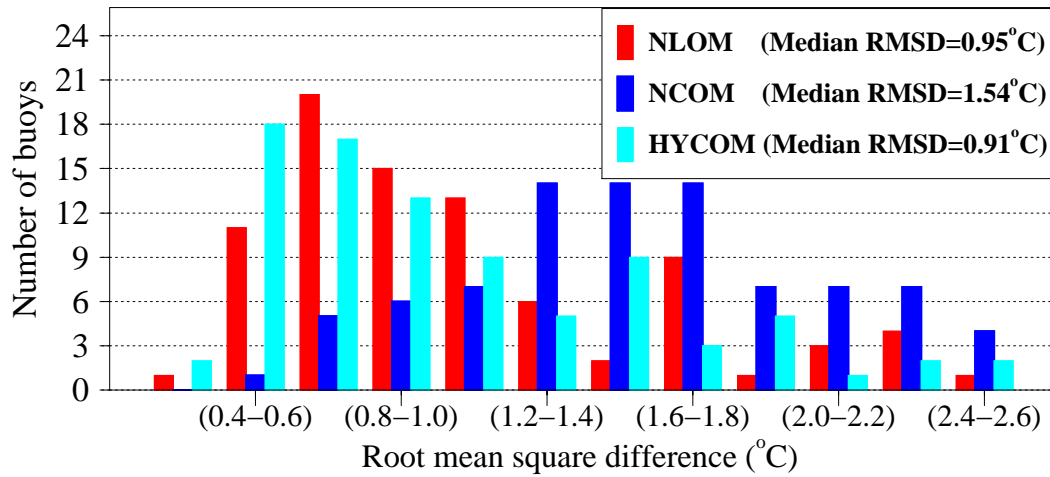
11.0 vs R&S SST: Skill Score yr 25



Interannual SST Comparisons

- Identify year-long time series at fixed locations
 - Always SST
 - Sometimes atmospheric fields
 - Sometimes subsurface T and/or S
- Compare observations to free-running and assimilative ocean models
 - HYCOM 0.72 global, free running (ECMWF or NOGAPS)
 - NLOM 1/8 near-global, free running ECMWF
 - NCOM 1/8 global, free running FNMOC and assimilative
- NLOM/NCOM 1/8 degree is 1/6 degree equatorial
 - 4x finer than HYCOM

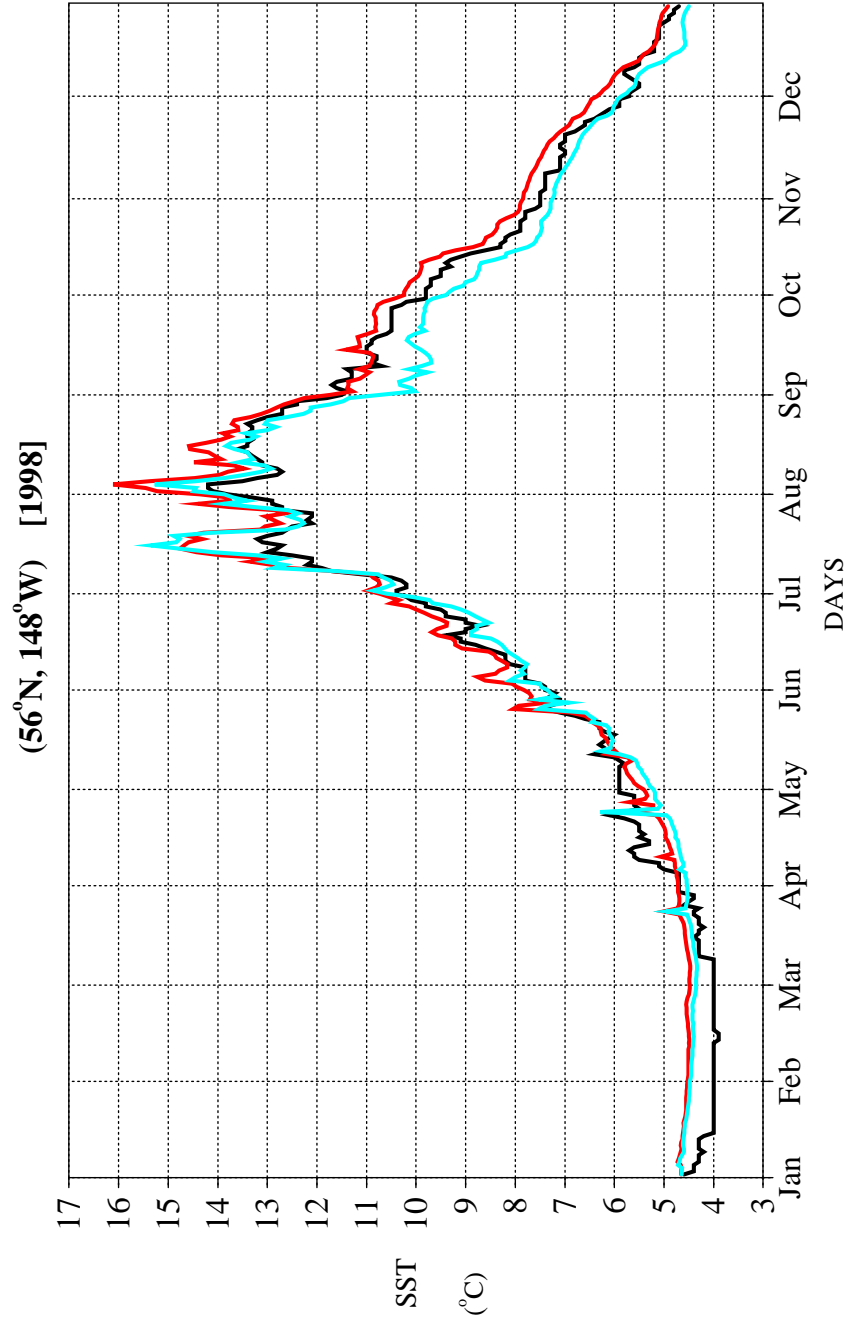
**Free-running HYCOM, NCOM and NLOM with no assimilation of SST
Comparisons with 86 year-long daily buoy time series (1998–2000)**

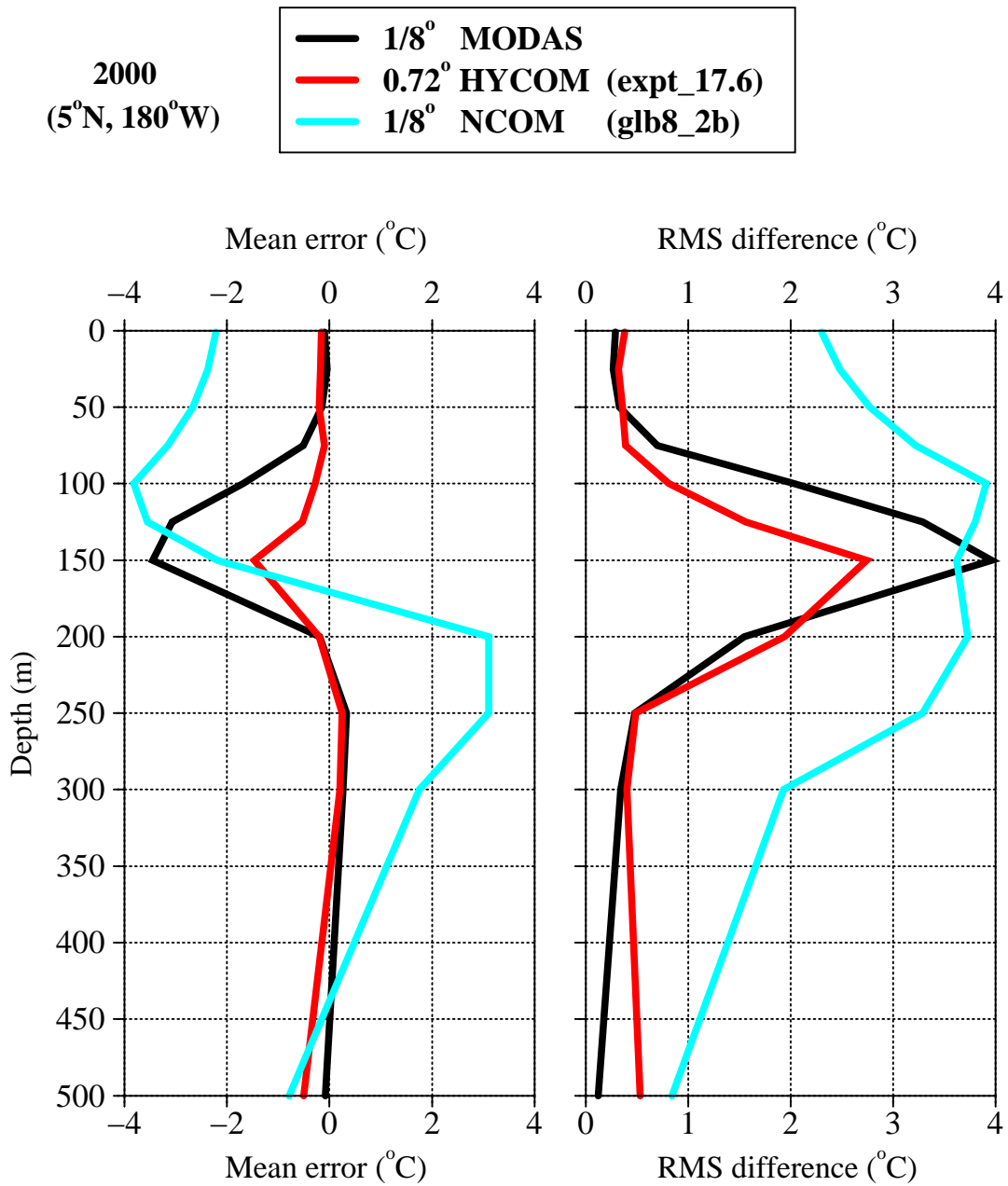


1/8° NLOM uses wind and thermal forcing from ECMWF

1/8° NCOM uses wind and thermal forcing from NOGAPS

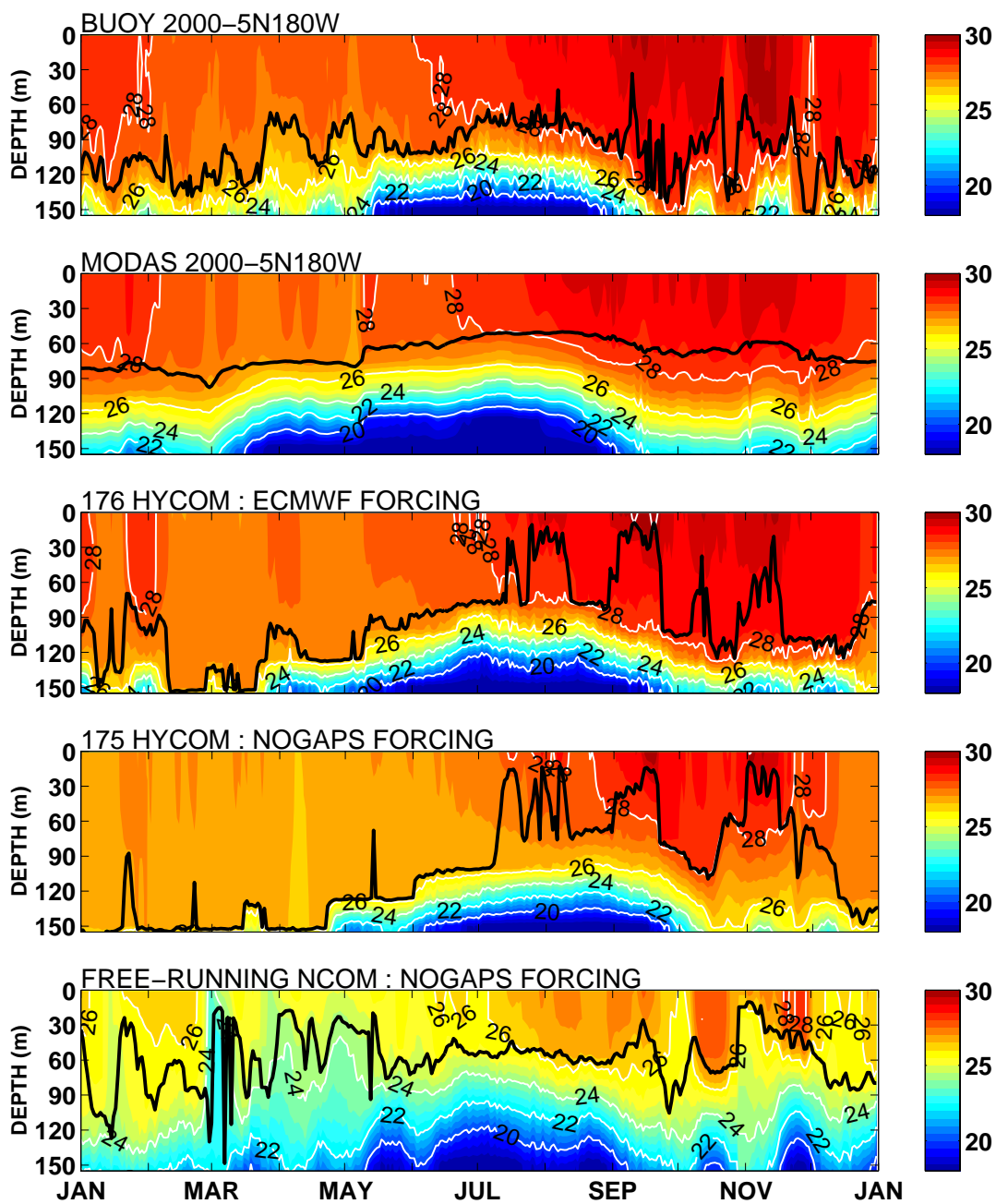
0.72° HYCOM uses wind and thermal forcing from ECMWF

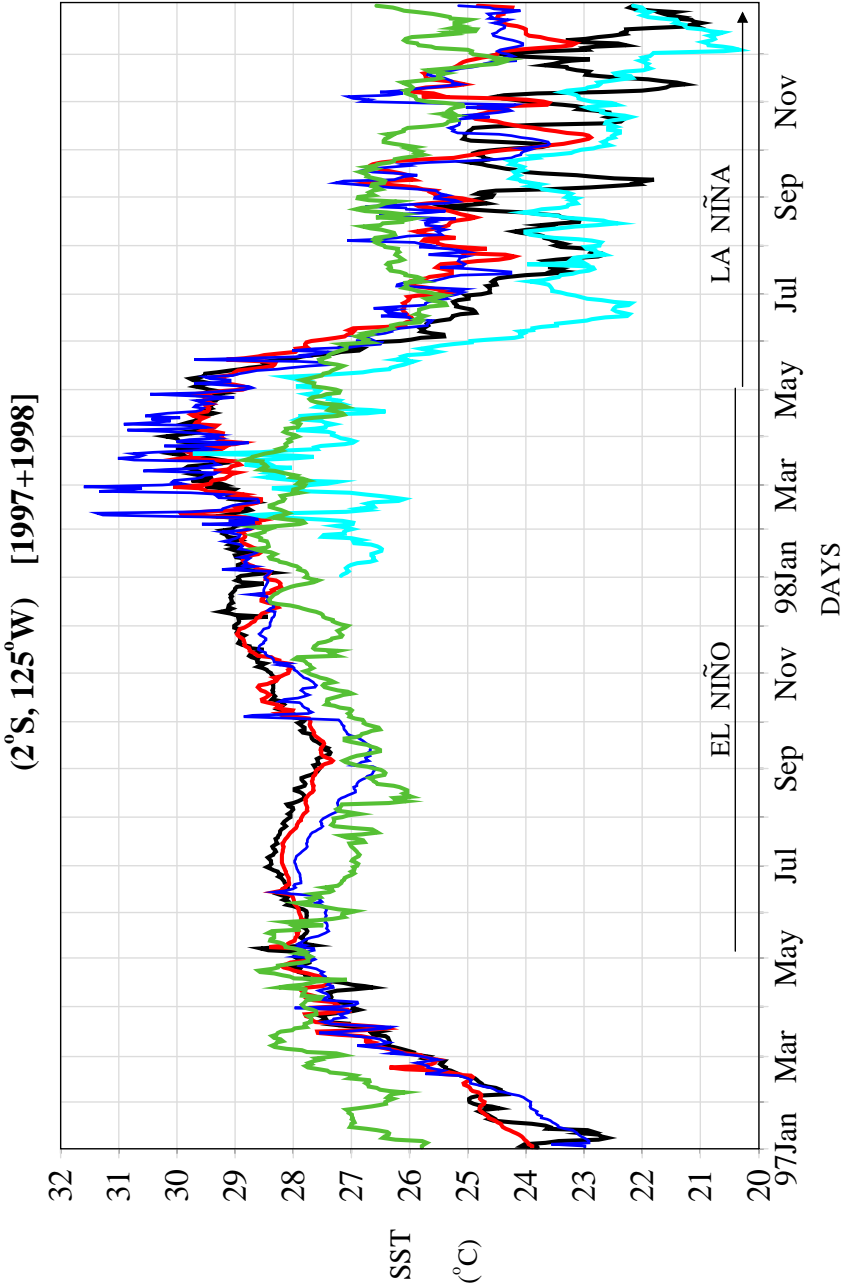
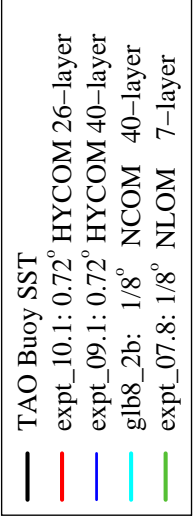


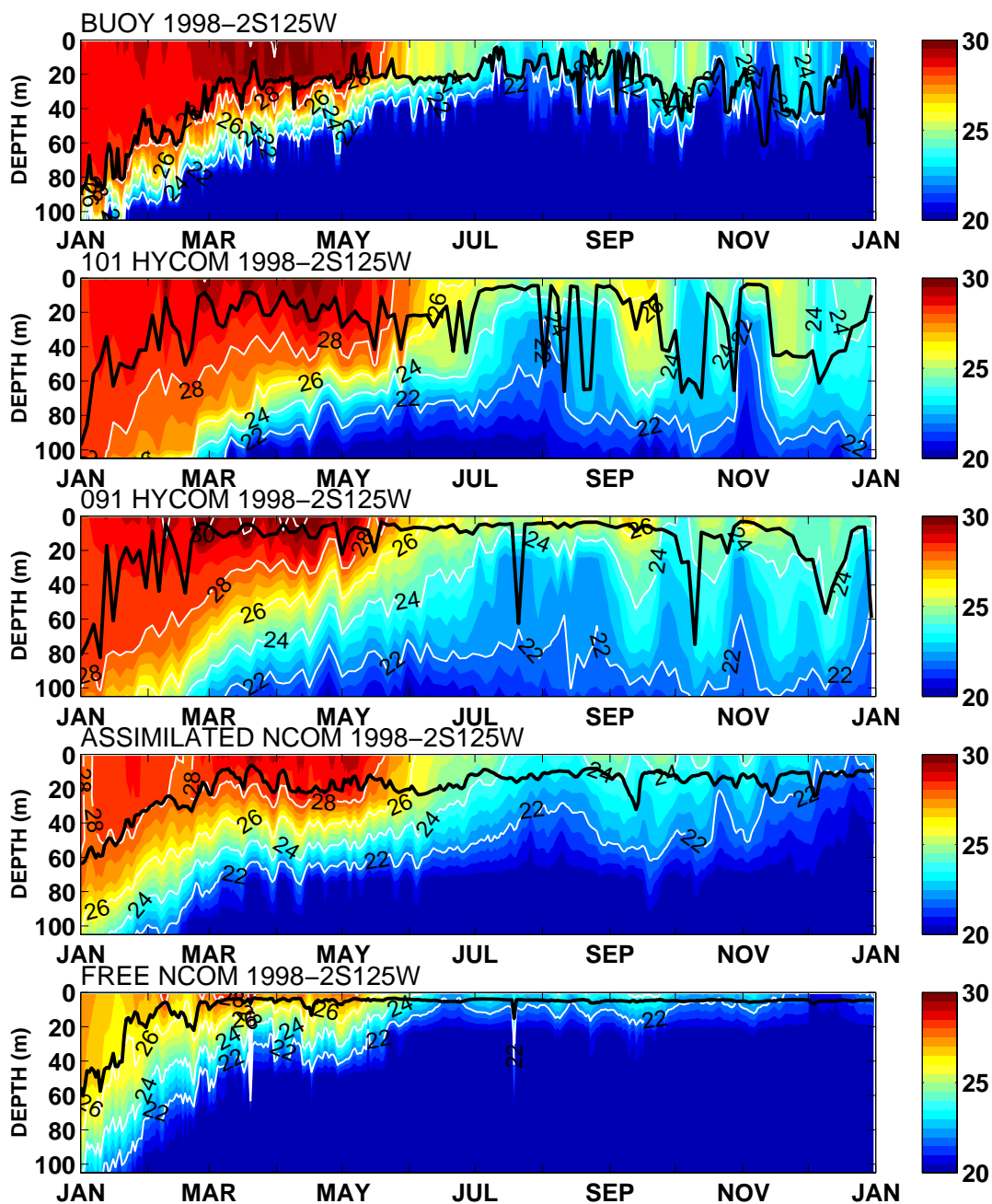


Error statistics with respect to buoy (365 days)

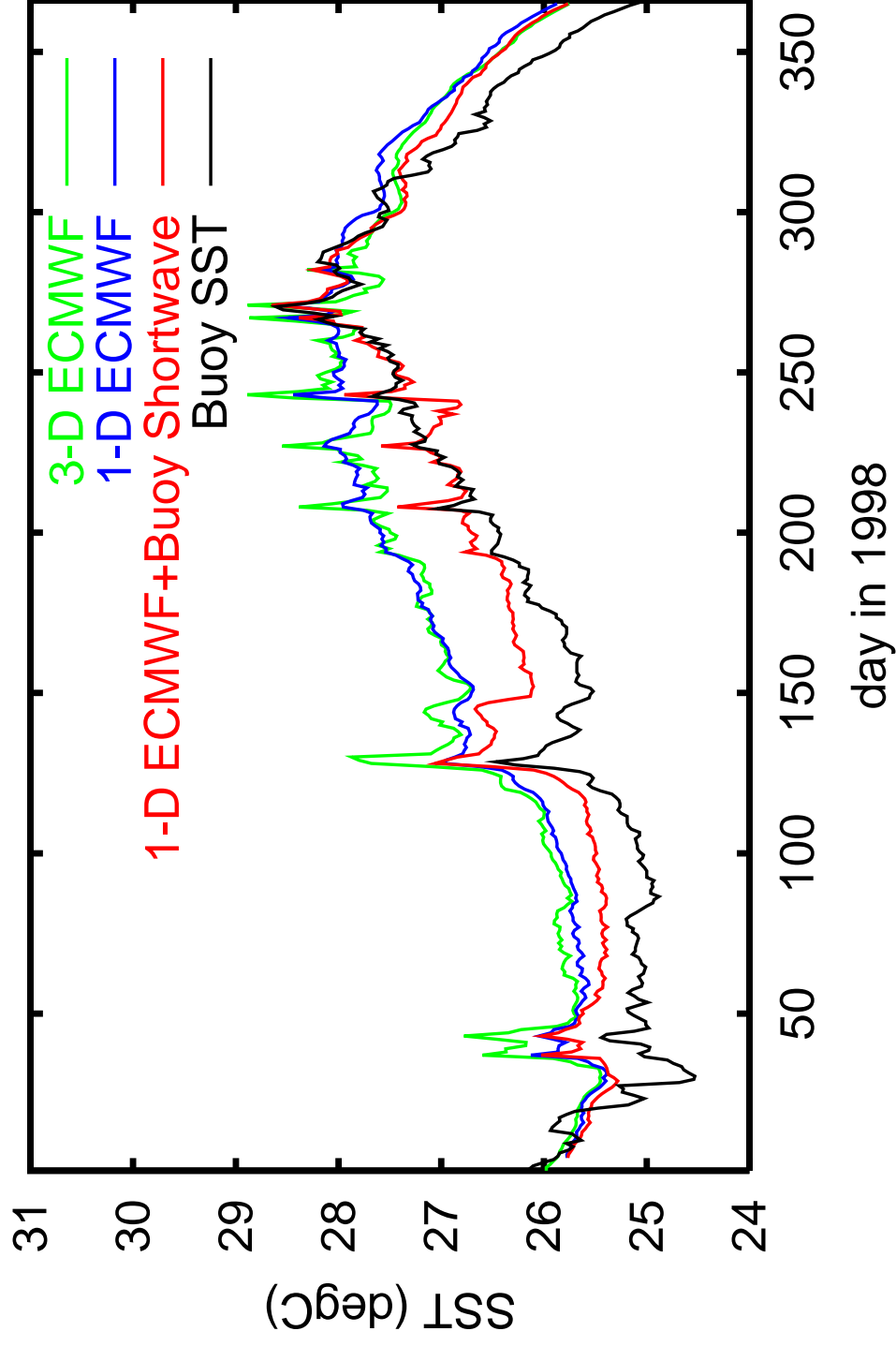
ps: HYCOM and NCOM are free—running simulations







HYCOM (KPP) vs Buoy at 38W, 15N in 1998



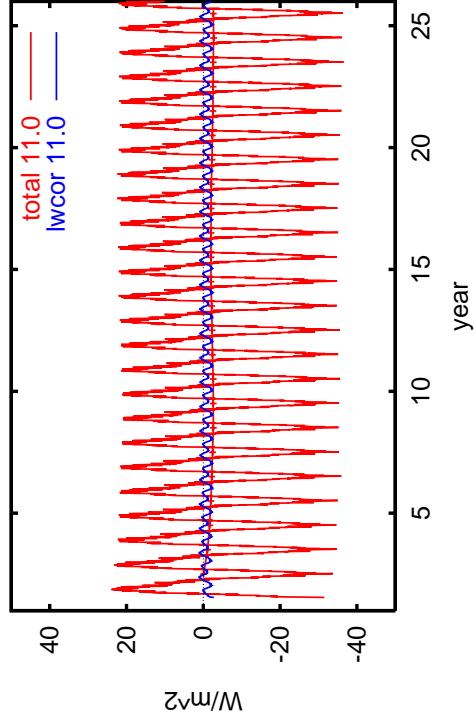
Conclusions (SST)

- Global 0.72 degree SST is similar to that in higher resolution Atlantic and Pacific simulations (not shown)
- KPP is performing well in HYCOM
- Thinner deep isopycnal layers are a major improvement on the equator
- Skill in southern mid-high latitudes and northern (Atlantic) high latitudes needs improving
- Most of the SST error is in the annual mean
- Not yet clear how much is due to forcing and how much due to KPP
 - If it is due to forcing, we can apply a correction

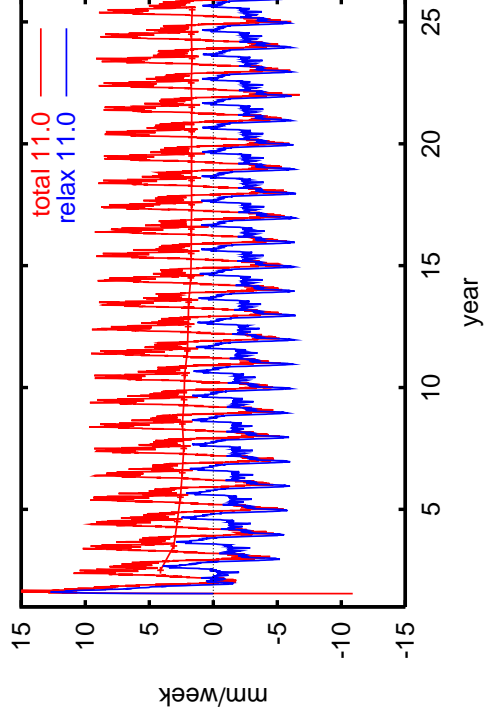
Long Term Trends

- Most cases run only 5 years, but 11.0 has run 25 years
- No significant trend in SST or SSS
- No significant trend in heat flux or E-P
- Probably too little sea ice
 - Antarctic extent shrinks over time
- Some basin-wide averages show a trend
 - SSH increasing by 5 mm/year, rate changing -0.1 mm/year
 - * Steric change, i.e. lighter average density
 - Average T warming by 0.6 degC/century
 - * Even though net heat flux is cooling
 - Average S freshening by 0.05 psu/century
 - * Net E-P is also freshening
- We need to find a way to equilibrate SSH (density)

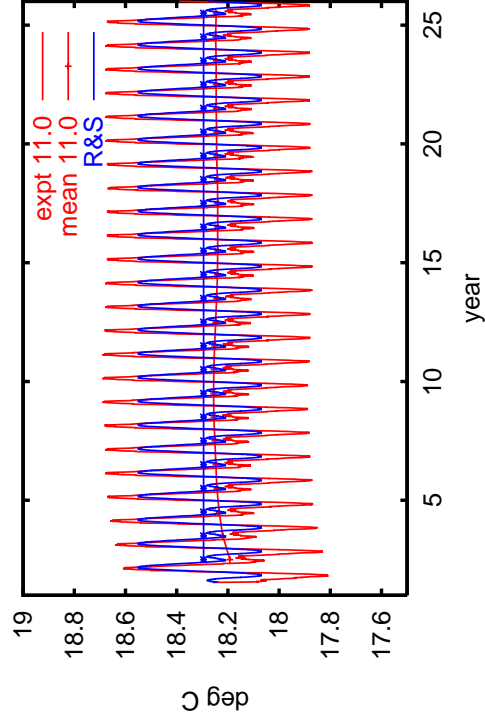
Global 0.72deg, Basin-Wide Mean Heat Flux



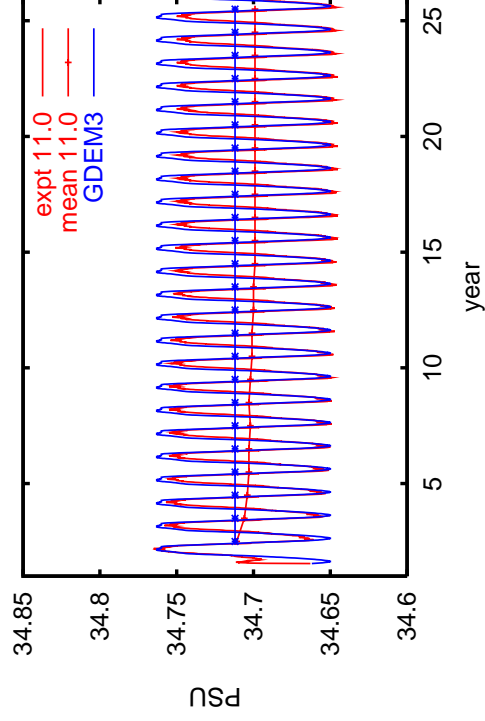
Global 0.72deg, Basin-Wide Mean Surface P-E Flux

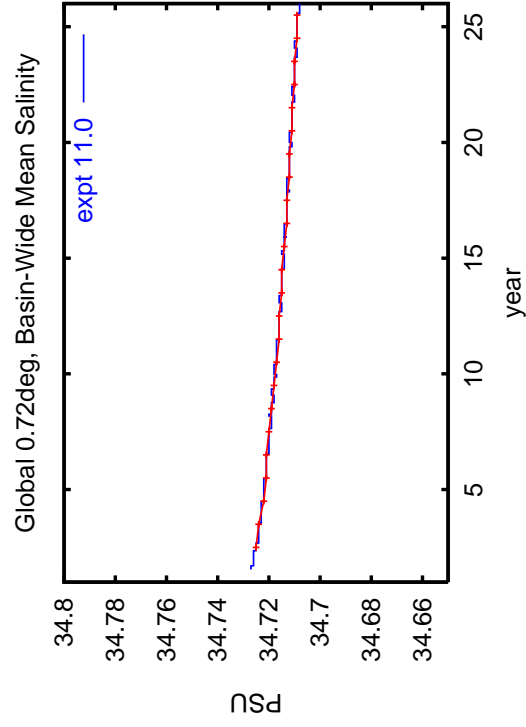
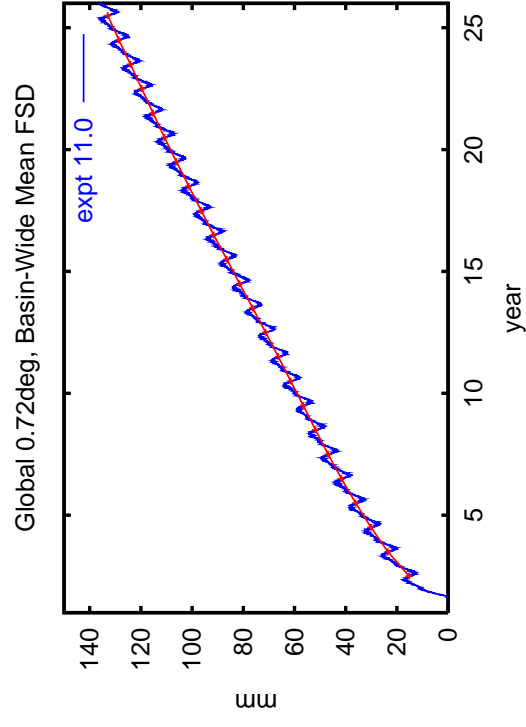
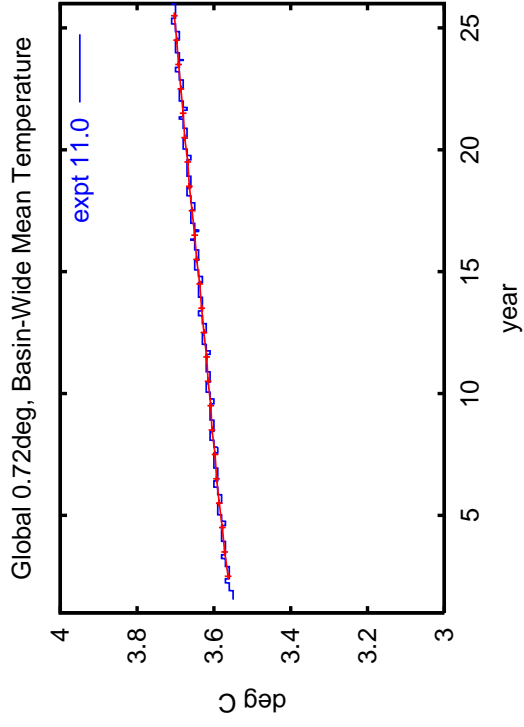
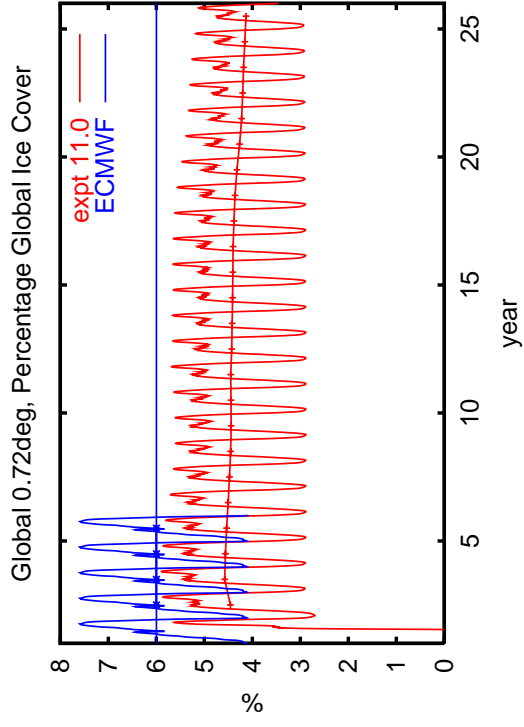


Global 0.72deg, Basin-Wide Mean SST



Global 0.72deg, Basin-Wide Mean SSS





Thermohaline Circulation

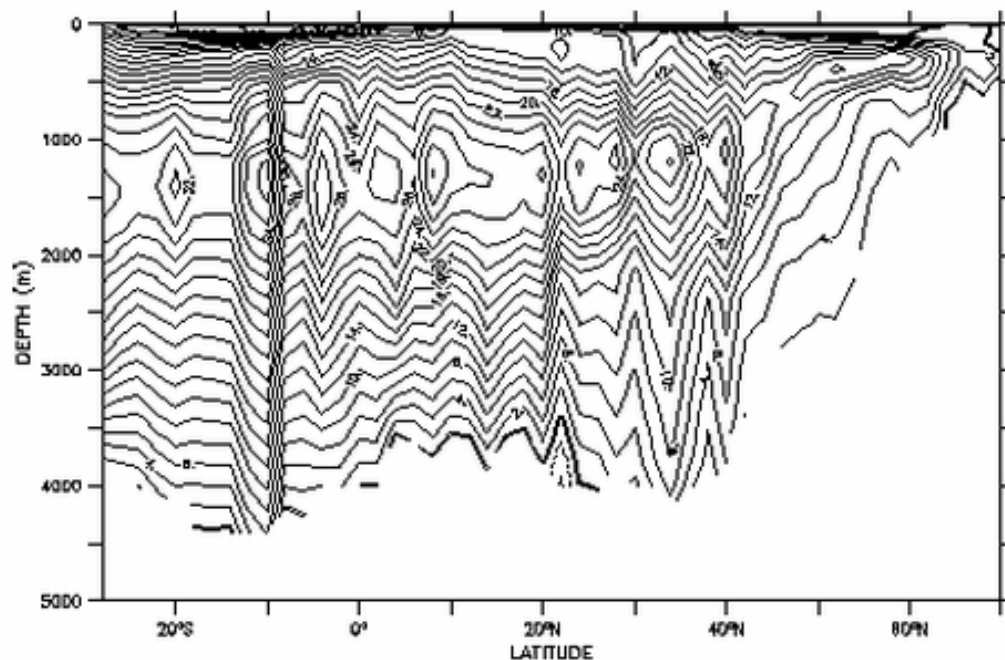
- North Atlantic Overturning StreamFunction
 - Initially very strong in 11.0 (sigma-theta)
 - Weakens over time
- σ_{2^*} would presumably be better
 - But reference state isn't simultaneously stable in Antarctic and Labrador Sea

HYCOM Ver. 5.7.3
NOAA/PMEL TMAP
Aug 14 2005 09:00:00

TIME : 07-JUL-0005 12:00

DATA SET: 110_archMNA.0005_sfz_atl.nc

HYCOM GLBa0.72 (Atlantic Ocean)



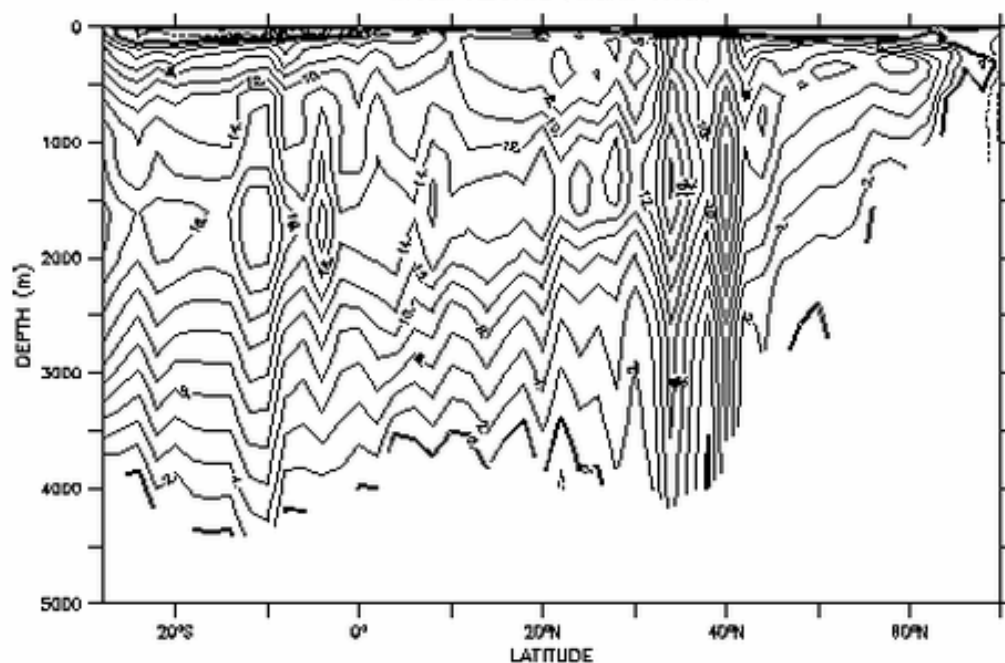
TRANSPORT_STREAM_FUNCTION (Sv)

HYCOM Ver. 5.7.3
NOAA/PMEL TMAP
Aug 14 2005 09:00:00

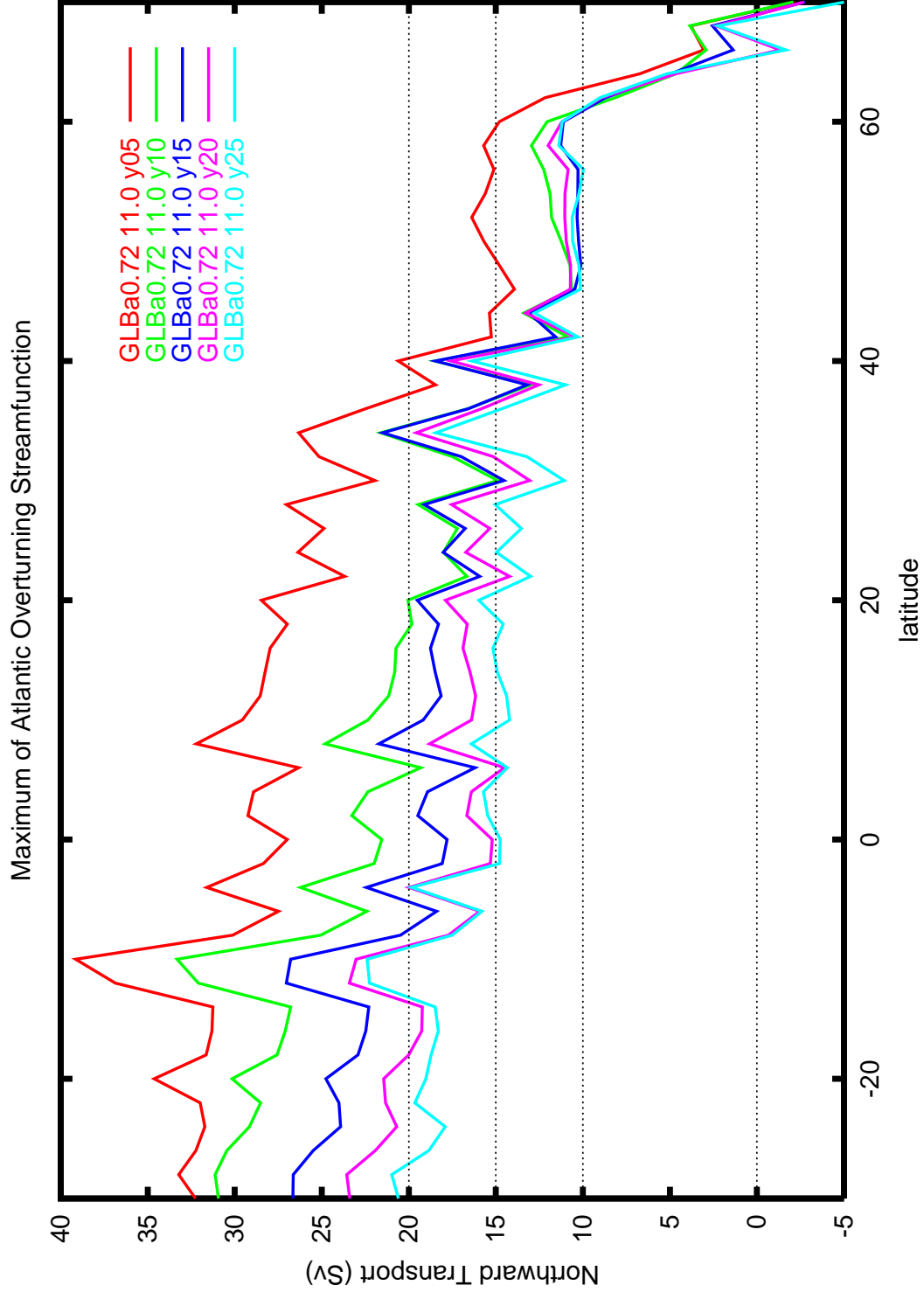
TIME : 22-JUL-0025 12:00

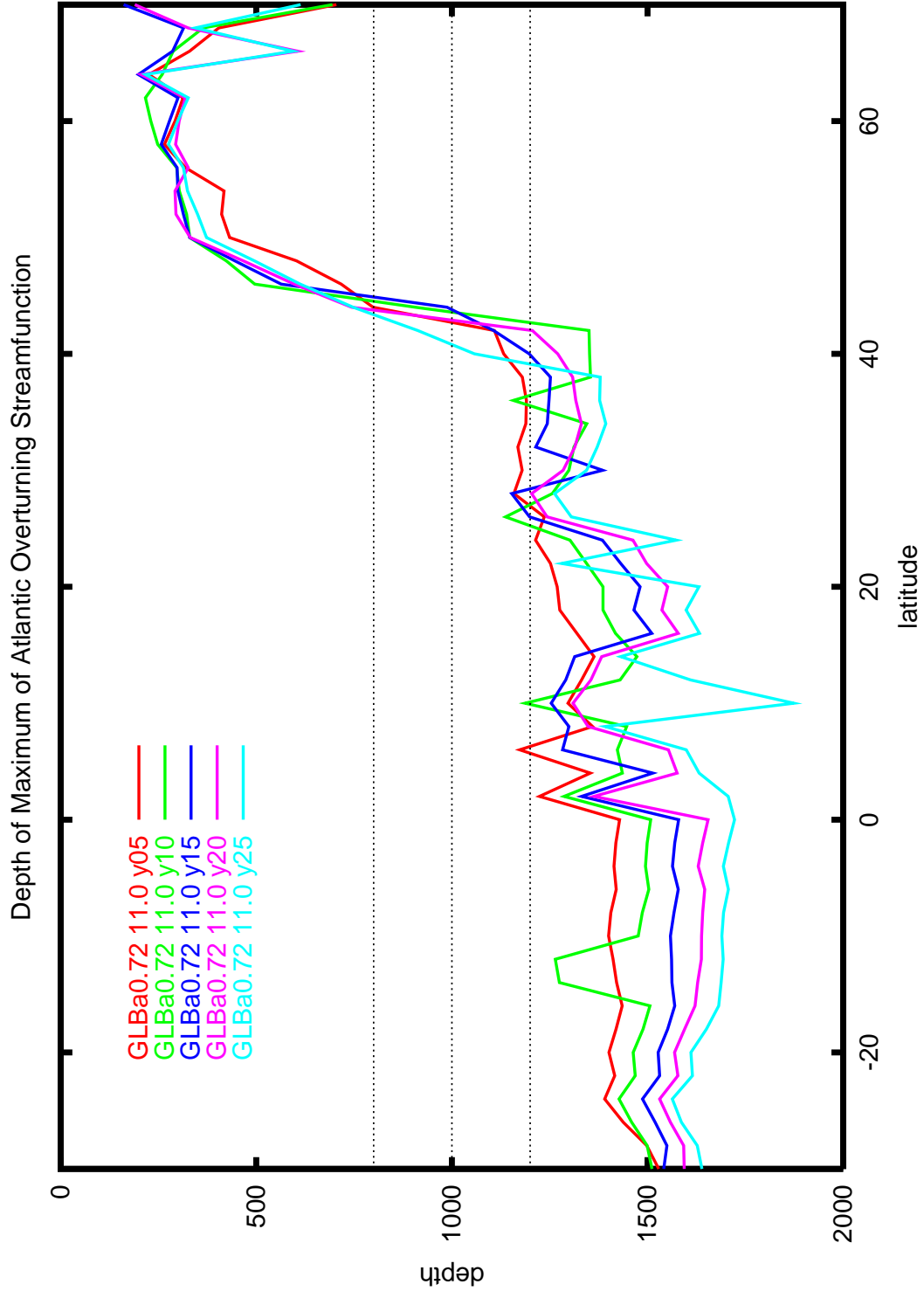
DATA SET: 110_archMNA.0025_sfz_atl.nc

HYCOM GLBa0.72 (Atlantic Ocean)



TRANSPORT_STREAM_FUNCTION (Sv)





Thermobaricity in Global Models

- Need σ_2 to represent AABW
- Need thermobaricity to get a good SSH with σ_2
- MICOM/HYCOM include thermobaricity via “virtual potential density” (σ_2^*)
 - Compressibility coefficient from a reference T&S
- Scheme is unstable if actual T&S are very different from reference T&S
- No single reference T&S works globally
- Tried using combination of two reference states
 - 3 degC and 35 psu north of 30N
 - 0 degC and 34 psu south of 30S
 - weighted sum between 30N and 30S
- Tested the method by shrinking the transition zone
 - Expt 16.1: 30S-30N (as above)
 - Expt 16.3: 30S-25S
 - Expt 16.4: 25N-30N
- This approach does not appear viable
- What else can we try?

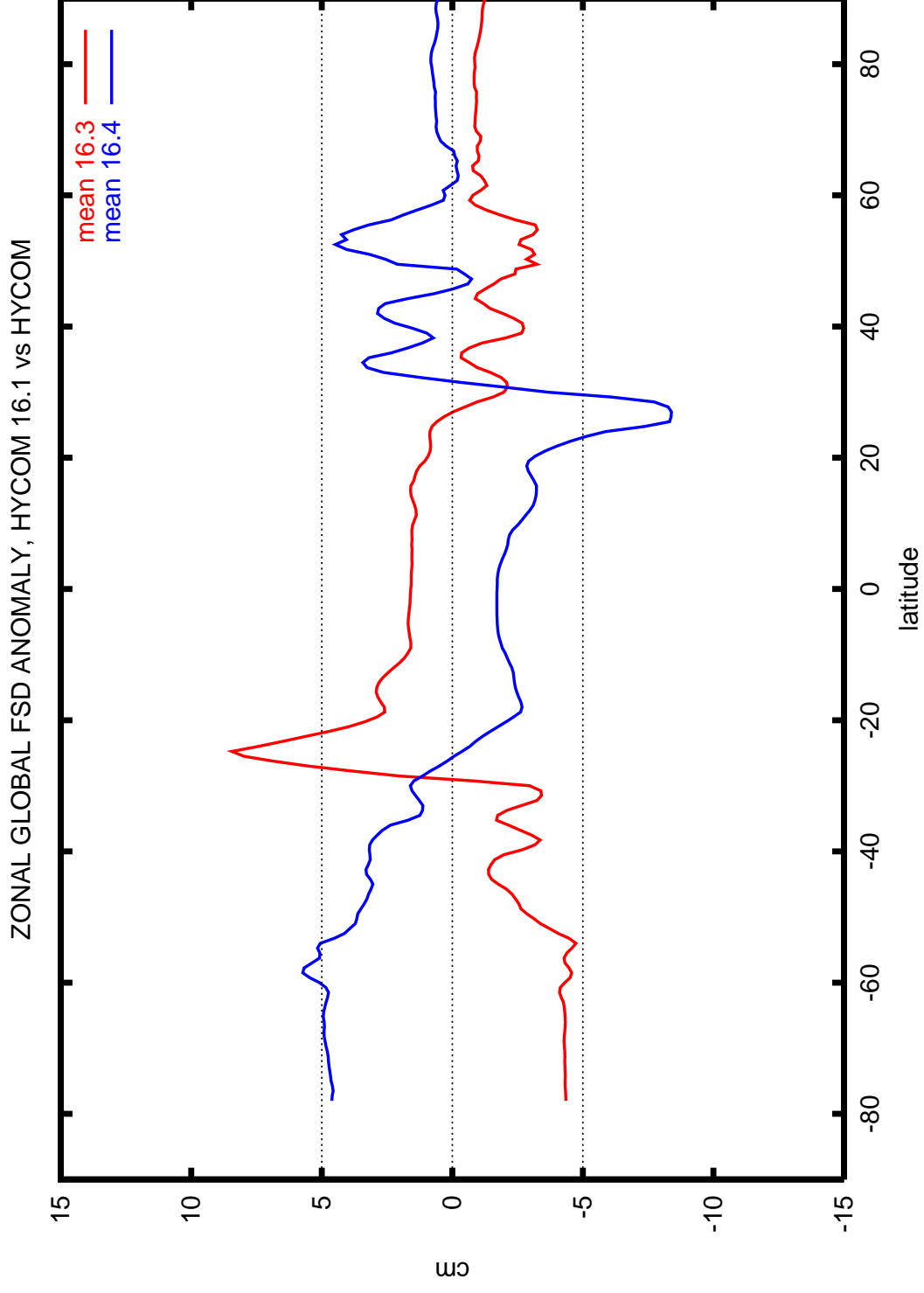
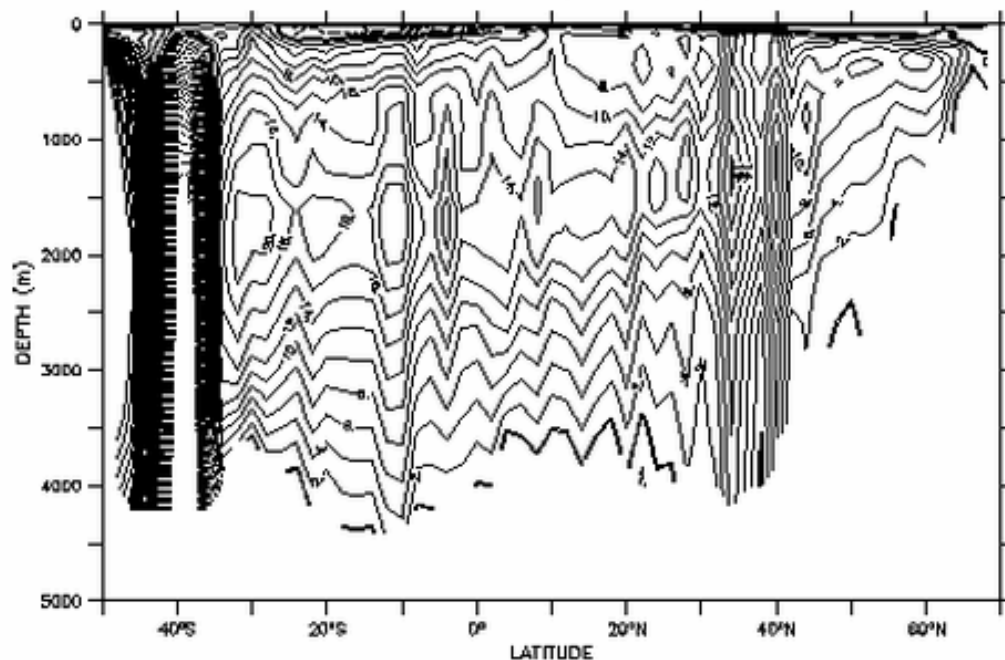


FIGURE 11.12
HYCOM GLBa0.72
July 11, 2005 11:42:00

TIME : 22-JUL-0025 12:00

DATA SET: 110_archMNA.0025_sfz_atl.nc

HYCOM GLBa0.72 (Atlantic Ocean)



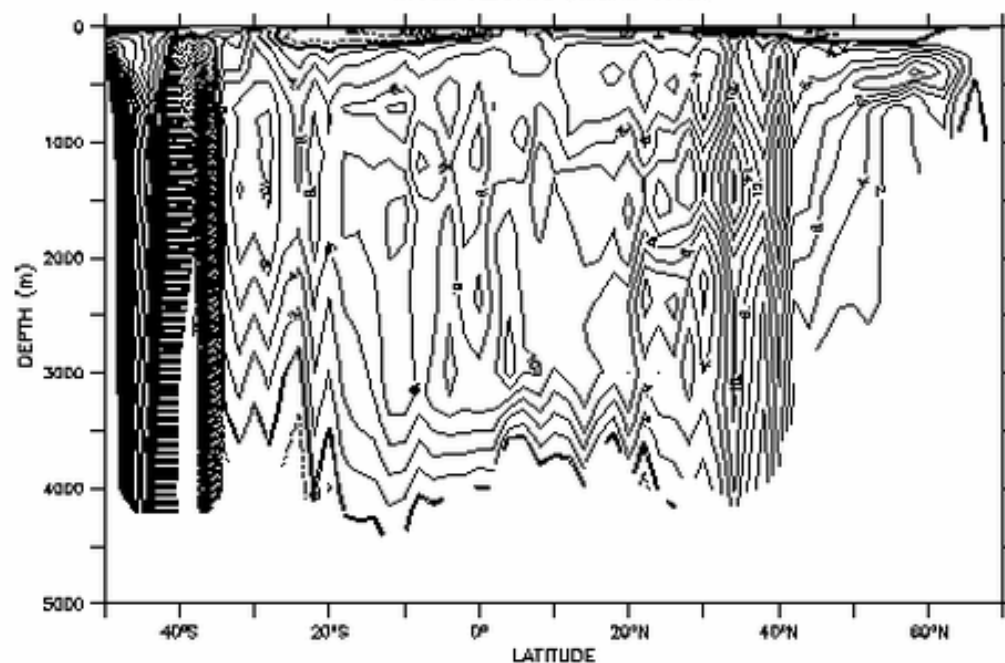
TRANSPORT_STREAM_FUNCTION (Sv)

FIGURE 11.13
HYCOM GLBa0.72
July 11, 2005 11:42:00

TIME : 07-JUL-0005 12:00

DATA SET: 181_archMNA.0005_sfz_atl.nc

HYCOM GLBa0.72 (Atlantic Ocean)



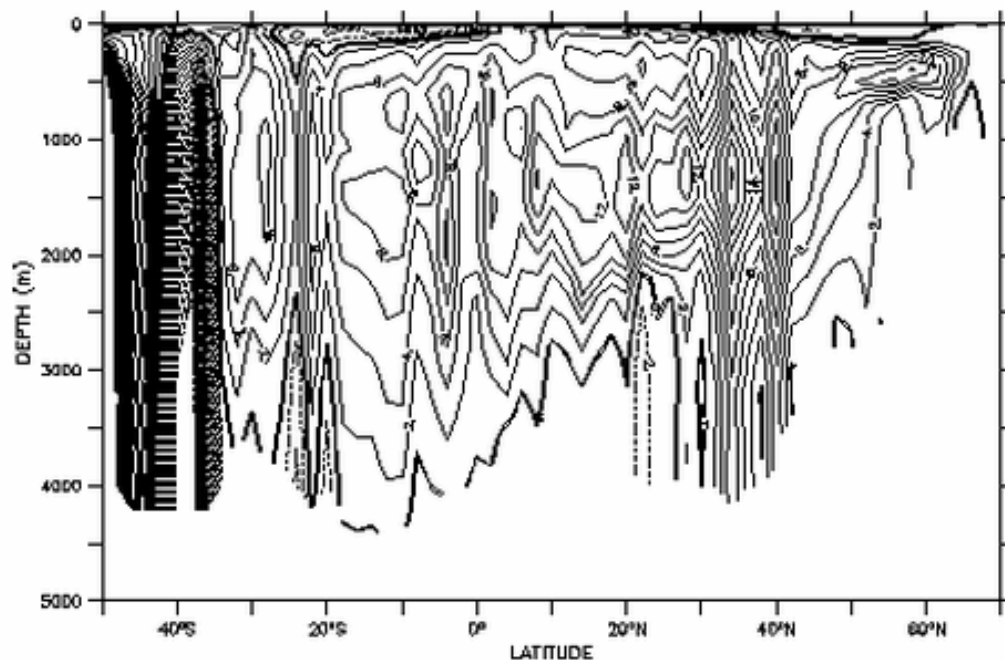
TRANSPORT_STREAM_FUNCTION (Sv)

HYCOM Ver. 5.7.3
NOAA/PMEL TMAP
Comp. 1.4.2005 11:43:03

TIME : 07-JUL-0005 12:00

DATA SET: 183_archMNA.0005_sfz_atl.nc

HYCOM GLBa0.72 (Atlantic Ocean)



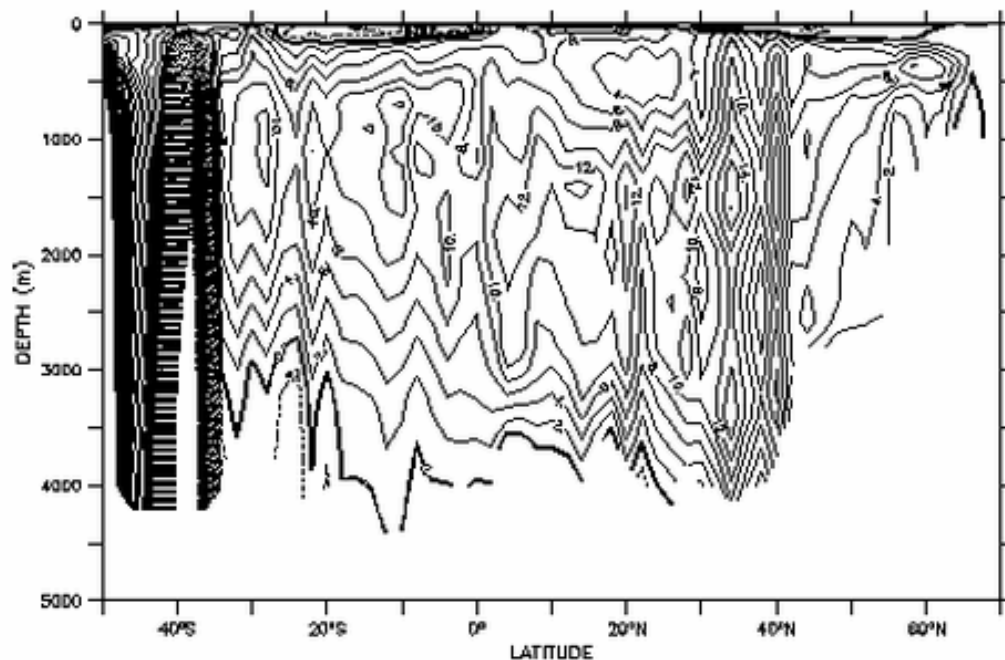
TRANSPORT_STREAM_FUNCTION (Sv)

HYCOM Ver. 5.7.3
NOAA/PMEL TMAP
Comp. 1.4.2005 11:43:03

TIME : 07-JUL-0005 12:00

DATA SET: 184_archMNA.0005_sfz_atl.nc

HYCOM GLBa0.72 (Atlantic Ocean)



TRANSPORT_STREAM_FUNCTION (Sv)

Future Work

- In FY04, most of global effort will be at 0.24 degrees
 - Perhaps a 0.08 degree “demo” run
- Continue to concentrate on “free running” SST
 - KPP vs GISS
 - Corrections for atmospheric biases
 - Interannual comparisons to buoys
- Other issues:
 - Add CICE sea ice model
 - * How to evaluate sea ice skill
 - SSH/density drift
 - Thermobaricity
 - SST assimilation
 - What is the optimal surface salinity forcing